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THE PLANET OF NO RETURN

HUMAN RESILIENCE ON AN ARTIFICIAL EARTH

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Being responsible stewards of the Anthropocene will require embracing the ecological benefits of increasing agricultural productivity and livable cities.

Over the last several decades, a consensus has grown among scientists that humans have become the dominant ecological force on the planet. According to these scientists, we are now living in the Anthropocene, a new geological epoch shaped by humans[1]. While some have hailed this forward-looking vision of the planet, others have linked this view with the perennial concern that human civilization has exceeded the carrying capacity of Earth's natural systems and may thus be fundamentally unsustainable.[2] In this article, I argue that this latter notion rests upon a series of assumptions that are inconsistent with contemporary science on how humans interact with ecosystems, as well as with most historical and archeological evidence.Ever since early humans discovered fire and the benefits of collaborative systems such as collective hunting and social learning, human systems, not the classic biophysical limits that still constrain other species, have set the wider envelope for human population growth and prosperity. It was not planetary boundaries, but human system boundaries that constrained human development in the Holocene, the geological epoch that we have just left. We should expect no less in the Anthropocene.

Humans have dramatically altered natural systems — converting forests to farmlands, damming rivers, driving some species to extinction and domesticating others, altering the nitrogen and carbon cycles, and warming the globe — and yet the Earth has become more productive and more capable of supporting the human population.[3] This process has dramatically intensified in recent centuries at a rate unprecedented in Earth's (and human) history,[4] but there is little evidence to date that this dynamic has been fundamentally altered. While the onset of the Anthropocene carries new ecological and social risks, human systems such as agriculture have proven extraordinarily resilient to environmental and social challenges, responding robustly to population pressures, soil exhaustion, and climate fluctuations over millennia, from a global perspective.

Though the sustainability of human civilization may not be at stake, we must still take our responsibilities as planetary stewards more seriously than ever. As the scale and power of human systems continue to increase at accelerating rates, we are awakening to a new world of possibilities — some of them frightening. And yet our unprecedented and growing powers also allow us the opportunity to create a planet that is better for both its human and nonhuman inhabitants. It is an opportunity that we should embrace.

1.

Long before the Holocene, Paleolithic human systems had already evolved powers beyond those of any other species, managing to engineer ecosystems using fire, to innovate collective strategies for hunting, and to develop other tools and techniques that revolutionized human livelihoods from hunting and foraging.[5] The extinction of megafauna across most of the terrestrial biosphere demonstrates the unprecedented success of early human engineering of ecosystems.[6] Those extinctions had cascading effects (trophic downscaling) caused by the loss of dominant species, leading to forest loss in some regions and forest regrowth in others.[7] Paleolithic humans, with a population of just a few million, dramatically transformed ecosystems across most of the terrestrial biosphere and most coastal ecosystems,[8] demonstrating that population size is not the main source of the transformative power of human systems.

The onset of the Holocene, which began with the end of the last ice age, roughly corresponds with the start of the Neolithic Age of human development. During this period, agricultural human systems began to displace earlier Paleolithic human systems,[9] and human systems became dependent upon the entirely novel, unambiguously anthropogenic process of clearing native vegetation and herbivores and replacing them with engineered ecosystems populated by domesticated plant and animal species.[10] This process allowed available land and resources to support many more people and set the stage for massive and sustained human population growth way beyond what was possible by Paleolithic systems. In ten millennia, the human population surged from just a few million to billions today.[11]

While the warm and stable climate of the Holocene is widely credited with enabling the rise of agriculture, more complex forms of human social organization, and the general thriving of human populations to a degree far exceeding that of the prior epoch, it was not these new climatic and biophysical conditions themselves that brought the Paleolithic era to an end. Rather, Paleolithic human systems failed to compete with a new human system built upon a series of profound technological innovations in ecosystem engineering.[12]

The dramatic, sustained rise of agricultural populations, along with their eventual success in dominating Earth's most productive lands, demonstrates that the main constraints on these populations were not environmental.[13] The Malthusian model holds that populations are ultimately limited by their environmental resources — primarily the ability of a given area of land to provide adequate food.[14] But this model makes little sense when engineered ecosystems have long been the basis for sustaining human populations.

Throughout the world, food production has risen in tandem with the density of agricultural populations. Populations work harder and employ more productive technologies to increase the productivity of land only after it becomes a limiting resource. This results in a complex interplay of population growth, labor inputs, technology adoption, and increased productivity — a process of agricultural intensification that still continues in many developing agricultural regions today.[15]

Until the widespread commodification of agricultural production over the last century or so, agriculturalists — and likely their Paleolithic hunting and foraging predecessors — used the minimal amount of labor, technologies, and other resources necessary to support their livelihoods on the lands available to them.[16] In most regions, yield-boosting technologies, like the plow and manuring, had already been developed or introduced long before they became necessary to overcome constraints on local food availability for subsistence populations.[17] Improving agricultural productivity facilitated rising population growth and density and placed greater pressure on food production, which, in turn, induced the adoption of more productive agricultural technologies.

While this steady increase in the productivity of land use in tandem with population seems to conflict with the environmental degradation classically ascribed to human use of land,[18] the theoretical explanations for this are simple and robust. The low-density populations of early farmers tended to adopt long-fallow shifting cultivation systems (rotations of 20 years and longer), progressing through short-fallow shifting cultivation, annual cropping, multiple cropping, and the increasing use of irrigation and fertilizers as populations grew and land became scarce.[19]

Cultivation of agricultural land has resulted in all manner of environmental degradation at local scales. Although agricultural productivity inevitably declines after land is first cleared for agriculture and in agricultural systems without intensive management, there is little evidence of declining long-term productivity in agricultural lands that have been managed intensively for millennia.[20] Indeed, the overwhelming trend is quite the opposite.[21] Increasing demands upon the productivity of agricultural lands have resulted in an increasing demand for technological inputs (and labor, in the preindustrial era) in order to maintain and increase productivity, which continues to rise in most agricultural regions.

2.

The long trends toward both the intensification of agricultural cultivation and the engineering of ecosystems at increasing scope and scale have accelerated as more and more of the world transitions from rural and agricultural societies to urban and industrial ones. The exponential growth in population, resource use, technologies, and social systems over the past half-century marks the most rapid and powerful transformation of both Earth and human systems ever.[22]

In the past two centuries, fossil energy has mostly replaced biomass for fuel and substituted for most human and animal labor,[23] revolutionizing the human capacity for ecosystem engineering, transport, and other activities. Large-scale industrial synthesis has introduced artificial compounds almost too numerous to count,[24] including a wide variety used to control undesired species.[25] Synthetic nitrogen fertilizers have helped to both double the amount of biologically reactive nitrogen in the Earth system and have largely replaced the use of native soil fertility in sustaining human populations.[26] Genetic engineering has accelerated gene transfer across species.[27] The waste products of human systems are felt almost everywhere on land, water, and air, including emissions of carbon dioxide rapid enough to acidify the oceans and change the climate system at rates likely unprecedented in Earth's history.[28] Wild fish and forests have almost disappeared,[29] receding into the depths of our ancestral memory.

At the same time, advances in hygiene and medicine have dramatically increased human health and life expectancy.[30] Industrial human systems are far more connected globally and evolve more rapidly than prior social systems, accelerating the pace of social change and interaction, technological innovation, material exchange, as well as the entire tempo of human interactions with the Earth system.[31] Over the last two centuries (and especially the past fifty years) most humans have enjoyed longer, healthier, and freer lives than we ever did during the Holocene.

There is no sign that these processes or their dynamics are slowing down in any way — an indication of their resilience in the face of change.[32] As far as food and other basic resources are concerned, we remain far from any physically determined limits to the growth and sustenance of our populations.[33] For better or for worse, humans appear fully capable of continuing to support a burgeoning population by engineering and transforming the planet.

3.

While human societies are likely to continue to thrive and expand, largely unconstrained by any hard biophysical boundaries to growth, this trend need not be inconsistent with conserving and even restoring a solid measure of our ecological inheritance. As populations, consumption, and technological power advance at an exponential pace, industrial systems appear to be evolving in new directions that tend to reverse many of the environmental impacts caused by agriculture and prior human systems.

Urbanization, perhaps the most powerful global change process of the industrial age, is rapidly concentrating human populations across the world into the market-based economies of cities, decoupling most of humanity from agricultural livelihoods and direct interactions with rural lands.[34] And while urbanization is nothing new, its current scale and rate are unprecedented.[35]

Urban economies of scale, particularly in human interactions and infrastructure, accrue as a result of population density and lead to improvements and additional advantages in nearly all aspects of human systems, including better health care, incomes, housing, access to markets, transportation, and waste treatment among many others.[36] Urban populations also tend to experience much lower and declining birth rates.[37]

Yet the greatest global effects of urbanization may be realized outside of cities, which occupy less than one percent of Earth's ice-free land. Rural-to-urban migration leads to the depopulation of rural landscapes, and massive urban demand for food and resources leads to the upscaling of agricultural systems.[38] The process is complex, but such trends tend to concentrate production in Earth's most productive agricultural lands, boosting agricultural yields in these areas through intensive use of inputs and technology by large-scale farming operations.[39] Depending on whether governance systems are in place to take advantage of these transformative powers of urbanization, large-scale forest recoveries can and have taken place in response to the widespread abandonment of marginal agricultural lands.[40]

As a result, massive urbanization may ultimately prove yet another stage in the process of agricultural intensification. In this case, increasing human population densities in urban areas drive ever increasing productivity per unit area of land, while at the same time allowing less productive lands to recover. Multifunctional landscape management may then support both intensive food production and habitat recovery for native and other desirable species.[41]

4.

With urbanization shaping the Industrial Age, and as we move rapidly into the most artificial environments we have ever created, the decisions we must make are ever clearer. Indeed, even as urbanization drives advances in some forms of agricultural productivity, the trend is rapidly spelling an end to some of the most ancient and productive agricultural human systems the world has ever seen — the ancient rice paddies of Asia are being transformed into factory floors. As we did at the end of the Paleolithic, most of humanity is defecting from the older ways, which will soon become hobbies for the elite and nostalgic memories for the rest of humanity. Just as wild forests, wild game, and soon, wild fish disappear, so do the human systems associated with them.

While there is nothing particularly good about a planet hotter than our ancestors ever experienced — not to mention one free of wild forests or wild fish — it seems all too evident that human systems are prepared to adapt to and prosper in the hotter, less biodiverse planet that we are busily creating. The "planetary boundaries" hypothesis asserts that biophysical limits are the ultimate constraints on the human enterprise.[42] Yet the evidence shows clearly that the human enterprise has continued to expand beyond natural limits for millennia. Indeed, the history of human civilization might be characterized as a history of transgressing natural limits and thriving. While the Holocene's relatively stable conditions certainly helped support the rise and expansion of agricultural systems, we should not assume that agriculture can only thrive under those particular conditions. Indeed, agriculture already thrives across climatic extremes whose variance goes far beyond anything likely to result from human-caused climate change.

The Earth we have inherited from our ancestors is now our responsibility. It is not natural limits that will determine whether this planet will sustain a robust measure of its evolutionary inheritance into the future. Our powers may yet exceed our ability to manage them, but there is no alternative except to shoulder the mantle of planetary stewardship. A good, or at least a better, Anthropocene is within our grasp. Creating that future will mean going beyond fears of transgressing natural limits and nostalgic hopes of returning to some pastoral or pristine era. Most of all, we must not see the Anthropocene as a crisis, but as the beginning of a new geological epoch ripe with human-directed opportunity. **/**

ENDNOTES:

[1] Crutzen, Paul J. 2002. *Geology of Mankind. Nature,* 415 (6867): 23-32.

[2] Marsh, George P. 1865. *Man and Nature: or, Physical Geography as Modified by Human Action.* New York: Scribner. 560.; Rockstrom, Johan, et al. 2009. “A safe operating space for humanity.” *Nature*. 461(7263), 472-475.; Ellis, Erle C., and N. Ramankutty. 2008. “Putting people in the map: anthropogenic biomes of the world.” *Frontiers in Ecology and the Environment*. 6(8): 439-447.

[3] Raudsepp-Hearne, Clara, et al. 2010. “Untangling the Environmentalist's Paradox: Why Is Human Well-being Increasing as Ecosystem Services Degrade?” *BioScience*. 60: 576-589.

[4] Turner II, B.L., et al. 1990. *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere Over the Past 300 Years*. New York: Cambridge University Press with Clark University. 713.; Steffen, Will, et al. 2004. *Global Change and the Earth System: A Planet Under Pressure*. 1st ed. Global Change: The IGBP Series. Berlin: Springer-Verlag. 332.

[5] Smith, B.D. 2007. “The ultimate ecosystem engineers.” *Science*. 315(5820): 1797-1798.; Clark, J.D., and J.W.K. Harris. 1985. “Fire and its roles in early hominid lifeways.” *African Archaeological Review*. 3(1): 3-27.; Bliege, Bird R., et al. 2008. “The “fire stick farming” hypothesis: Australian Aboriginal foraging strategies, biodiversity, and anthropogenic fire mosaics.” *Proceedings of the National Academy of Sciences.* 105(39): 14796-14801.

[6] Estes, James A., et al. 2011. “Trophic Downgrading of Planet Earth.” *Science*. 333(6040): 301-306. AND Johnson, Christopher N. 2009. “Ecological consequences of Late Quaternary extinctions of megafauna.” *Proceedings of the Royal Society B: Biological Sciences.* 276(1667): 2509-2519.; Wardle, David A., et al. 2011. “Terrestrial Ecosystem Responses to Species Gains and Losses.” *Science.* 332(6035): 1273-1277.

[7] Koch, P.L., and A.D. Barnosky. 2006. “Late Quaternary Extinctions: State of the Debate.” *Annual Review of Ecology, Evolution, and Systematics.* 37(1): 215-250.; Bowman, D.M.J.S., et al. 2009. “Fire in the Earth System.” *Science.* 324(5926): 481-484.

[8] Ambrose, Stanley H. 2001. “Paleolithic technology and human evolution.” *Science*. 291(5509): 1748-1753.; Smith, Bruce D. 2007. “The ultimate ecosystem engineers.” *Science.* 315(5820): 1797-1798.; Hamilton, Marcus J., et al. 2009. “Population stability, co-operation, and the invasibility of the human species.” *Proceedings of the National Academy of Sciences.* 106(30): 12255-12260.; Estes, James A., et al. 2011. “Trophic Downgrading of Planet Earth.” *Science*. 333(6040): 301-306.

[9] Grigg, D.B. 1974. *The Agricultural Systems of the World: an Evolutionary Approach*. Cambridge: Cambridge University Press. 358.; Gignoux, Christopher R., Henn, Brenna M., and Joanna L. Mountain. 2011. “Rapid, global demographic expansions after the origins of agriculture.” *Proceedings of the National Academy of Sciences.* 2011. 108(15): 6044-6049.

[10] Smith, B.D. 2007. “The ultimate ecosystem engineers.” *Science*. 315(5820): 1797-1798.; Diamond, Jared. 2002. “Evolution, consequences and future of plant and animal domestication.” *Nature.* 418(6898): 700-707.; Purugganan, Michael D., and Dorian Q. Fuller. 2009.

The nature of selection during plant domestication. *Nature.* 457(7231): 843-848.

[11] Grigg, D.B. 1974. *The Agricultural Systems of the World: an Evolutionary Approach*. Cambridge: Cambridge University Press. 358.; Weisdorf, Jacob L. 2005. "From Foraging To Farming: Explaining The Neolithic Revolution." *Journal of Economic Surveys.* 19(4): 561-586.

[12] Gignoux, Christopher R., Henn, Brenna M., and Joanna L. Mountain. 2011. "Rapid, global demographic expansions after the origins of agriculture." *Proceedings of the National Academy of Sciences.* 2011. 108(15): 6044-6049.

[13] Cohen, Joel E. 1995. "Population growth and Earth's human carrying capacity." *Science.* 269: 341-346.

[14] Malthus, Thomas R. 1798. *An Essay on the Principle of Population, as it Affects the Future Improvement of Society, with Remarks on the Speculations of Mr Godwin, M. Condorcet, and other writers.* London: J. Johnson. 3-143.

[15] Netting, Robert M. 1993. *Smallholders, Householders: Farm Families and the Ecology of Intensive Sustainable Agriculture.* Stanford, CA: Stanford University Press. 416.; Boserup, Ester. 1965. *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure.* London: Allen & Unwin. 124.; Tiffen, Mary, Mortimore, Michael, and Francis Gichuki. 1994. *More People, less Erosion: Environmental Recovery in Kenya*. edn. John Wiley & Sons Ltd.; Ellis, Erle C., and S.M. Wang. 1997. "Sustainable traditional agriculture in the Tai Lake Region of China. *Agriculture, Ecosystems & Environment.* 61(2-3): 177-193.

[16] Weisdorf, Jacob L. 2005. "From Foraging To Farming: Explaining The Neolithic Revolution." *Journal of Economic Surveys.* 19(4): 561-586.; Boserup, Ester. 1965. *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure.* London: Allen & Unwin. 124.

[17] Grigg, D.B. 1974. *The Agricultural Systems of the World: an Evolutionary Approach*. Cambridge: Cambridge University Press. 358.; Netting, Robert M. 1993. *Smallholders, Householders: Farm Families and the Ecology of Intensive Sustainable Agriculture.* Stanford, CA: Stanford University Press. 416.

[18] Raudsepp-Hearne, Clara, et al. 2010. "Untangling the Environmentalist's Paradox: Why Is Human Well-being Increasing as Ecosystem Services Degrade?" *BioScience*. 60: 576-589.; Dale, T. and V.G. Carter. 1955. *Topsoil and Civilization.* Norman, OK: University of Oklahoma Press. 270.

[19] Boserup, Ester. 1965. *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure.* London: Allen & Unwin. 124.; Boserup, Ester. 1981. *Population and Technological Change: A Study of Long Term Trends.* Chicago: University of Chicago Press. 255.; Turner II, B.L., Hanham, Robert Q., and Anthony V. Portararo. 1977. "Population Pressure and Agricultural Intensity." *Annals of the Association of American Geographers.* 67(3): 384-396.; Netting, Robert M. 1993. *Smallholders, Householders: Farm Families and the Ecology of Intensive Sustainable Agriculture.* Stanford, CA: Stanford University Press. 416.; Ruddiman, William F. and Erle C. Ellis. 2009. "Effect of Per-Capita Land use Changes on Holocene Forest Clearance and CO2 Emissions." *Quaternary Science Reviews*. 28: 3011-3015.

[20] Ellis, Erle C., and S.M. Wang. 1997. "Sustainable traditional agriculture in the Tai Lake Region of China. *Agriculture, Ecosystems & Environment.* 61(2-3): 177-193.

[21] Grigg, D.B. 1974. *The Agricultural Systems of the World: an Evolutionary Approach*. Cambridge: Cambridge University Press. 358.; Netting, Robert M. 1993. *Smallholders, Householders: Farm Families and the Ecology of Intensive Sustainable Agriculture.* Stanford, CA: Stanford University Press. 416.

[22] Steffen, Will, Crutzen, Paul J., and John R. McNeill. 2007. "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature." *AMBIO: A Journal of the Human Environment*. 36(8): 614-621.

[23] Ibid.

[24] Alloway, B.J. and D.C. Ayres. 1997. *Chemical Principles of Environmental Pollution. 2nd ed. Water, Air, & Soil Pollution.* New York: Chapman & Hall. 102: 416.

[25] Matson, P.A., et al. 1997. "Agricultural intensification and ecosystem properties." *Science.* 277(5325): 504-509.

[26] Smil, Vaclav. 1991. "Population growth and nitrogen: an exploration of a critical existential link." *Population and Development Review.* 17(4): 569-601.

[27] Dale, Philip J., Clarke, Belinda, and Eliana M.G. Fontes. 2002. "Potential for the environmental impact of transgenic crops." *Nature Biotechnology.* 20(6): 567-574.

[28] Steffen, Will, et al. 2004. "Global Change and the Earth System: A Planet Under Pressure." 1st ed. *Global Change: The IGBP Series 2004.* Berlin: Springer-Verlag. 332.; Alley, Richard B, et al. 2007. *Climate Change 2007: The Physical Science Basis: Summary for Policymakers: Summary for Policymakers*. Intergovernmental Panel on Climate Change.

[29] Ellis, Erle C. and Navin Ramankutty. 2008. "Putting people in the map: anthropogenic biomes of the world." *Frontiers in Ecology and the Environment.* 6(8): 439-447.; Vitousek, P.M., et al. 1997. "Human domination of Earth's ecosystems." *Science.* 277(5325): 494-499.; Kareiva, Peter, et al. "Domesticated nature: shaping landscapes and ecosystems for human welfare." *Science.* 2007. 316(5833): 1866-1869.

[30] Fogel, R.W. and D.L. Costa. 1997. "A Theory of Technophysio Evolution, With Some Implications for Forecasting Population, Health Care Costs, and Pension Costs." *Demography.* 34(1): 49-66.

[31] Costanza, R., et al. 2007. "Sustainability or Collapse: What Can We Learn from Integrating the History of Humans and the Rest of Nature?" *AMBIO: A Journal of the Human Environment.* 36(7): 522-527.; Steffen, Will. 2009. *Looking Back to the Future. AMBIO: A Journal of the Human Environment.* 37(sp14): 507-513.

[32] Scheffer, Marten. et al. 2009. "Early-warning signals for critical transitions." *Nature.* 461(7260): 53-59.

[33] Cohen, Joel E. 1995. "Population growth and Earth's human carrying capacity." *Science.* 269: 341-346.; Franck, Siegfried, et al. 2011. "Harvesting the sun: New estimations of the maximum population of planet Earth." *Ecological Modelling.* 222(12): 2019-2026.

[34] Grimm, Nancy B., et al.. 2008. "Global Change and the Ecology of Cities." *Science.* 319(5864): 756-760.

[35]Grimm, Nancy B., et al.. 2008. "Global Change and the Ecology of Cities." *Science.* 319(5864): 756-760.; Bettencourt, Luis M.A., et al. 2007. "Growth, innovation, scaling, and the pace of life in cities." *Proceedings of the National Academy of Sciences.* 104(17): 7301-7306.; Brand, Stewart. 2009. *Whole Earth Discipline: An Ecopragmatist Manifesto.* Viking Penguin. 325.

[36] Bettencourt, Luis M.A., et al. 2007. "Growth, innovation, scaling, and the pace of life in cities." *Proceedings of the National Academy of Sciences.* 104(17): 7301-7306.

[37] Galor, Oded and David N. Weil. 2000. "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and beyond." *The American Economic Review.* 90(4): 806-828.

[38] Lambin, Eric F., et al. 2001. “The causes of land-use and land-cover change: moving beyond the myths.” *Global Environmental Change-Human and Policy Dimensions.* 11(4): 261-269.

[39] Green, Rhys E., et al. 2005. “Farming and the fate of wild nature.” *Science.* 307(5709): 550-555.

[40] Kareiva, Peter, et al. 2007. “Domesticated nature: shaping landscapes and ecosystems for human welfare.” *Science.* 316(5833): 1866-1869.; Green, Rhys E., et al. 2005. “Farming and the fate of wild nature.” *Science.* 307(5709): 550-555.; Perz, Stephen G. 2007. “Grand Theory and Context-Specificity in the Study of Forest Dynamics: Forest Transition Theory and Other Directions.” *The Professional Geographer*. 59(1): 105-114.; Rudel, Thomas K., et al. 2009. “Agricultural intensification and changes in cultivated areas, 1970-2005.” *Proceedings of the National Academy of Sciences.* 106(49): 20675-20680.

[41] Kareiva, Peter, et al. 2007. “Domesticated nature: shaping landscapes and ecosystems for human welfare.” *Science.* 316(5833): 1866-1869.; Green, Rhys E., et al. 2005. “Farming and the fate of wild nature.” *Science.* 307(5709): 550-555.

[42] Rockstrom, Johan, et al. 2009. “A safe operating space for humanity.” *Nature.* 461(7263): 472-475.