Earth 2020

An Insider's Guide to a Rapidly Changing Planet

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Land

Navin Ramankutty and Hannah Wittman

Our planet is two-thirds ocean, yet we call it Earth; perhaps because we have created our homes on the relatively small fraction of the surface that is covered by land. The land is where we grow our crops, graze animals, obtain forest products for housing and medicinal needs, consume and distribute marine resources and earn our livelihoods. Land use is a primary manifestation of a socio-ecological metabolism that takes up, transforms and expresses energy in the service of human culture, technological progress and capital accumulation.[1] In the age of the Anthropocene, human-driven land use has a bigger impact on the global environment than almost any other activity.

Humans have been modifying the Earth's land surface since time immemorial as part of nomadic and then increasingly sedentary and complex agricultural societies. Even the soil — the foundation of humanity's survival — has a deep anthropogenic history; human practices of forest burning and fertilization of agricultural lands have long marked the human domination of Earth's land surface. Today, about 40% of the world's ice-free land surface is used for growing crops or grazing animals.[2] By comparison, urban areas make up less than 5% of Earth's surface, yet this small area is home to over half the human population.[3] Human influence is also evident in much of the remaining lands that have not been cleared, with estimates suggesting that more than three quarters of the world's lands bear the footprint of our species.[4]

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To fully appreciate human impacts on Earth's surface, we can look to past drivers of global land use change, as we work to shift our practices towards a more sustainable future.[5] During the first stage of human history (the Paleolithic age, between about two million and ten thousand years ago), the use of stone tools and the control of fire enabled humans to migrate from their origins in East Africa to Eurasia, Australia and the Americas. The use of fire by Palaeolithic hunters changed landscapes and was also partly responsible for the extinction of megafauna. Observations of human-induced landscape burning can be traced to antiquity, as in a Carthaginian reference to western Africa around 500 years BC: '...during the day, we saw nothing but forests, but by night many burning fires ... we saw the land at night covered with flames. And in the midst there was one lofty fire, greater than the rest, which seemed to touch the stars'.[6]

The next stage of human history began with the domestication of plants and animals roughly 10,000 years ago.[7] This Neolithic Revolution occurred in several places around the world; first in Mesopotamia, China, eastern North America, New Guinea and the Sahel, and later on in Mesoamerica and the Andes. The advent of sedentary agriculture exerted further profound impacts on local landscapes. Both Plato and Aristotle commented on the soil erosion and deterioration of the hills and mountains of Greece. In describing the regional landscape, Plato wrote in *Critias*, 2400 years ago, that '...what now remains ... is like the skeleton of a sick man, all the fat and soft earth having wasted away, and only the bare framework of the land being left'.[8]

Fast forward a couple of thousand years, and we see that the most recent phase of human history has been marked by the human appropriation of energy stored in fossil fuels.[9] This began roughly 300 years ago, and was characterized by the rise of global trade networks, the advent of Industrial Revolution technologies and the dominance of capitalism. During this period, the extent and pace of human activities on the land surface accelerated drastically, as the global expansion of agriculture followed the development of human settlements and the world economy.[10] In 1700, large-scale agriculture was mainly confined to the Old World, in Europe, India, China and Africa. European colonization, a violent spatial 'fix' to the unmet food and energy needs of new industrial cities, created new settlement frontiers in the Americas, Australasia and South Africa (and was also responsible for cultural and linguistic genocide across several continents). At the same time, Russians moved east in the Former Soviet Union. The impact of this economic and agricultural development on Earth's surface has been dramatic. During the past three centuries, four times more land has been converted for human use than during all of prior human history.

During the past half-century, since the first Earth Day in 1970, agricultural expansion has taken a more complex turn. Agricultural frontiers in the tropics of Latin America, Southeast Asia and Africa have further expanded to meet the dietary needs of wealthy consumers in global cities, while other regions have seen abandonment of agriculture followed by regrowth of forests. Growing awareness of the importance of forest conservation for biodiversity and climate change mitigation has also led to an increase in protected areas across the globe; although rapid deforestation continues in many regions driven by global commodity markets for beef, soy, palm oil and sugar.[11] These shifts across the globe also correspond to the concentration of land ownership in higher-income countries, where aging farming populations struggle with farm succession and where government support for agriculture is concentrated in a few commodities such as maize, soy and wheat. At the same time, in lower-income countries, farms are becoming fragmented and are struggling with inequitable access to agricultural infrastructure.

Social and political trends over the past fifty years have driven a shift away from expansion of agricultural lands, toward more intensified use of existing areas. Although land clearing and deforestation continues in the tropics today, the total rate of cropland expansion over the last fifty years has been slower than in the previous two and half centuries. Yet, despite reduced clearing rates and reduced agricultural land area per-capita, global agricultural lands have continued to provide food and other agricultural products for the rapidly rising human population.

The apparent paradox of increased food production on a smaller per-capita land surface is a direct result of the so-called Green Revolution; the suite of technologies that enabled the yields of a small number of staple crops to increase rapidly since the 1950s.[12] The development of the Haber-Bosch process in the early twentieth century was particularly important, as it permitted the synthesis of nitrogen fertilizer from the plentiful (though biologically-inert) nitrogen in the atmosphere. This discovery was a major agricultural breakthrough, as nitrogen is a major limiting nutrient in soils. At the same time, scientific advances improved understanding of plant genetics and physiology, and their relationship to crop performance. Plant breeders were supported by both governments and private industry to develop new high yielding varieties of maize, wheat and rice that were able to effectively utilize the synthetic fertilizers that were rapidly deployed in the 1950s and 1960s, mainly in Latin America and Asia. These developments, coupled with low (subsidized) energy costs, allowed more capitalized farmers to efficiently exploit (and over-exploit) their soil and groundwater resources. Over the 1961–2014 period, the global area equipped for irrigation doubled, from 0.16 billion hectares (12% of cropland) to 0.33 million hectares (21% of cropland). As a result of new seed varieties, and additional nutrient, water and fossil energy inputs, per capita cereal production increased by 30% between 1961 and 2014.[13]

At the same time, public investment in just a small number of food crops has led to a rapid decline in agro-biodiversity. During the twentieth century, more than 90% of crop genetic diversity was lost to agriculture as farmers were encouraged by markets and public policies to shift their land use to fewer, higher-yielding varieties. The three plant species — rice, maize and wheat — that were the primary focus of the Green Revolution now contribute nearly 60% of the world's plant-based food supply. While urban consumers enjoy almost unlimited choice of foods in the supermarket (if they can afford it), just a few ingredients — wheat, maize and now soy — are found in most processed foods and nearly every meal of a typical North American diet.

The Green Revolution has been deemed a massive success by some scholars and policymakers, considering the overall increase in total global crop production.[14] Indeed, total calories produced increased more than 30% from 1961 to 2013, reaching an average of 2884 daily kcal per person, which is more than enough to meet the average minimum daily requirements of every person on Earth.[15] However, these calories are not distributed equally across the global food economy. The number of undernourished in the world remains unacceptably high at approximately 820 million people, and 2 billion suffer from micronutrient deficiencies. The global reliance on a few crops for energy is another primary reason for the human nutrition gap, with some 84% of global calories coming from just seventeen crops. On the flip side, excess and 'empty' calorie consumption has resulted in a global obesity epidemic, with around 37% of the world's population now overweight, carrying a heavy burden of non-communicable diseases such as diabetes, heart disease and certain cancers.

The unintended environmental consequences of the Green Revolution have burdened farmers, consumers and governments with new challenges in the management of sustainable land and food systems.[16] The clearing of forests and grasslands and the use of chemical fertilizers and pesticides have made agriculture the biggest driver of global biodiversity loss. Agriculture, forestry and other land uses also contributed nearly a quarter of global anthropogenic greenhouse gas emissions during the 2007–2016 period,[17] with 13% of carbon dioxide emissions resulting from tropical forest clearing, 44% of methane emissions from rice paddy cultivation, livestock enteric fermentation and manure, and 82% of all anthropogenic nitrous oxide emissions from excess fertilizer application (which quadrupled during 1961–2014). Moreover, irrigation now represents 70% of fresh water withdrawals around the world, and nitrogen and phosphorus loss from agricultural fields is the predominant driver of inland and coastal eutrophication.

The environmental impacts of agriculture and other associated land-use changes are also coupled to a suite of socio-economic factors. Poverty is a primary cause for the continued prevalence of malnutrition despite sufficient caloric availability at the national and global levels. A majority of the world's malnourished are poor farmers who are often hampered by the lack of land or secure land tenure, and an inability to acquire seeds or inputs to maintain soil fertility. Their poverty also creates a lack of resilience in the face of episodic losses resulting from extreme weather disasters (which may be increasing in frequency and intensity on a warming planet). Moreover, those farmers who are net producers of food (selling more than they buy) are adversely affected by low market prices in a globalized world. On the other hand, the urban poor, who are net buyers of food, are severely affected by food price hikes. The ability of individuals to access food is thus affected by the balance between income and food price, as well as their position in the global food system.

All in all, more than two billion people across the world remain malnourished, even as the expansion of global agriculture is arguably the single most important driver of global environmental degradation. One of the key United Nations Sustainable Development Goals is to 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture'.[18] How do we reduce food insecurity, feed the additional two to three billion people of the future, lower the environmental footprint of agriculture and make it more resilient to climate change — all at the same time?

This is, no doubt, a daunting challenge, but a number of wide-ranging solutions are now on the table. Many scholars recognize the need for continued increases in crop yields, particularly in areas characterized by high poverty rates with limited agricultural infrastructure such as irrigation, roads and markets. They call for sustainable intensification to produce more food at lower environmental costs, and argue that new agri-food technologies, such as precision agriculture and genetically modified (GM) foods are important components of this pathway. But others challenge this 'productivist paradigm', pointing out that increased food production is the wrong objective given the existing market failures that result in the poor global distribution of calories, and the fact that lower yields often reflect a lack of resources rather than technology. These scholars argue for a focus on food sovereignty, which advocates for growers and eaters to work together, along with scientists and the public sector, to develop regionally-adapted solutions for more equitable and ecological farming systems.[19] These systems employ agro-ecological methods like crop diversification and integration with animal agriculture to address soil nutrient deficiencies, while also contributing to dietary diversity and improved food security.

Looking ahead, numerous questions arise. There are many voices with differing opinions on how the world's land should be used and managed. Some believe in a top-down, regulatory approach, while others rely on the power of markets to determine what should be best done with the land. Still others suggest that local communities have the greatest incentives to protect their land-based resources, and should have the autonomy to make those decisions locally, recognizing that some voices have more influence than others. Further, we must understand that the current landscape results from the often unequal and unjust histories of past land ownership and use. Who decides how the land and food system challenges are framed and negotiated — from a local to a global scale — is as important as what happens on the land. There is no escaping the fact that global environmental challenges cannot be addressed without considering land-based solutions. Any such solutions will inherently involve trade-offs and inequities, which must be carefully considered in the design and implementation of effective, efficient and equitable policies for the future.

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