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# HARVESTING THE BIOSPHERE

## BY VACLAV SMIL

**Humanity has been harvesting an increasing share of the Earth's photosynthetic productivity. This has already resulted in a new world where the two species – cattle and people – dominate in mass terms but further losses lie ahead.**

When asked about the most important metrics to gauge the state of the modern civilisation, most of the readers of this publication would name such variables as annual GDP growth, foreign reserves, inflation rates or accumulated debt. Their e-counterparts in general, and the Silicon Valley crowd in particular, would insist on listing microchips following Moore's law, the omnipotent cloud, server capacities or the number of daily Facebook updates. A biologist must assume a great deal of self-control to call such notions misplaced and naïve. Existential requirements of Earth-based carbon-metabolising civilisations have not changed with the advent of hedge funds or Wi-Fi: photosynthesis is the world's most important energy conversion, and the set of techniques we have been deploying for millennia to manage it (called agriculture) is the most fundamental activity that keeps us all alive. Harvesting the biosphere (besides food for humans and feed for animals there are also fuels and raw materials, timber and pulp above all) is incomparably more important than corporate mergers and viral You-tube videos.

But we are amazingly adept at neglecting, even ignoring, the fundamentals and obsessing over ephemera. As a result, we do not have a sufficiently accurate understanding of our impact on the biosphere. We know that we have inflicted a great deal of harm and that some of the changes (if not irretrievable) will last for millennia: that explains the currently fashionable call for naming the period we live in the Anthropocene.[1] But quantitative understanding of many of these changes is weak, and this uncomfortable reality led me to take a closer look at the intensity with which the modern civilisation harvests the photosynthetic (primary) production of the biosphere. This intensity has been previously quantified in terms of the share of net primary productivity.

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NASA Global vegetation index map for October 2015 (darker green shows denser vegetation and hence higher net primary productivity).

http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD13A2_M_NDVI

Gross primary productivity (GPP) is the total of new plant mass photosynthesised during a given period of time, usually one year. A large part of it (typically 50%) is rapidly re-oxidised during autotrophic respiration (RA) that energises synthesis of complex carbohydrates, proteins and lipids require for plant growth and maintenance. Whatever remains is the net primary productivity (NPP).[2] That total currently amounts to about 60 billion tonnes of carbon (or 120 billion tonnes of dry plant matter) and before it is harvested by people as food, feed or wood (crop or wood yield) various shares of it are almost always somewhat consumed by wild organisms ranging from bacteria and insects to birds and mammals.

We now have excellent daily and monthly maps of global vegetation (See Image 1 below) but its harvests are much harder to quantify. Published rates of what has become commonly (but imprecisely) called human appropriation of NPP have ranged from as low as 10% to as much as 55%, and the mean of several major studies is 25%.[3] Obviously, the rates at or close to the uppermost level would be quite worrisome: if we are already taking out nearly half of annual photosynthetic productivity for food, feed, fuel and raw materials and future increases would bring us perilously close to the limit that should not be crossed in order to maintain many irreplaceable biospheric services ranging from maintaining adequate numbers of wild pollinators (whose numbers decline due to the application of agrochemicals) to preventing excessive soil erosion (its rates always rise in cultivated fields compared to natural ecosystems).

I wrote *Harvesting the Biosphere* in order to reduce the large existing uncertainty concerning the human impact on primary productivity. In order to avoid many numbers of large magnitude it is best to present some key results in relative terms.[4] I found that the global harvests of food and feed crops had doubled between 1900

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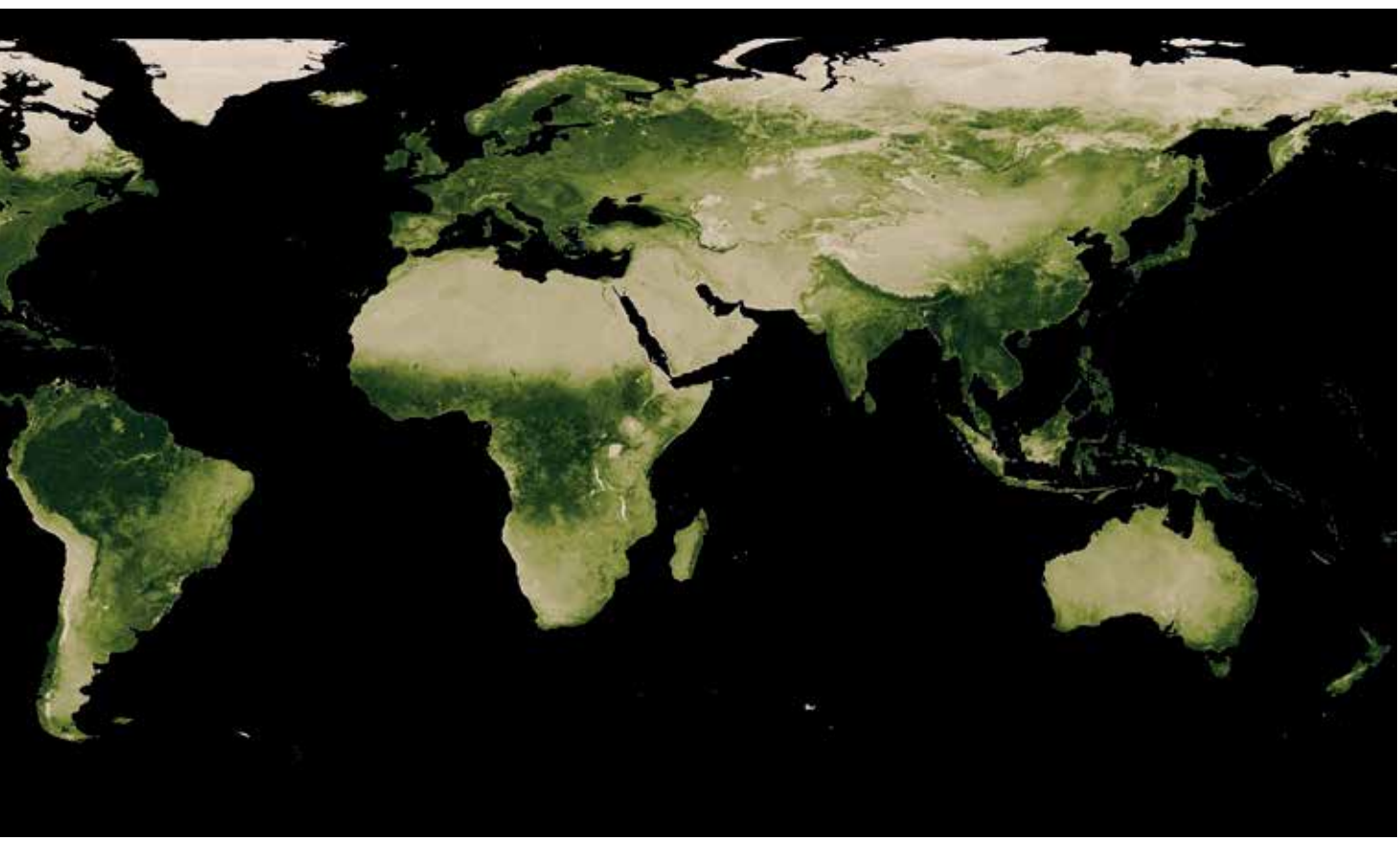

Night time photo of Europe from the International Space Station (France, Switzerland, parts of Italy, Spain, England, Low Countries and Germany) indicates to what extent our species has come to dominate the biosphere.

https://i.ytimg.com/vi/pKCjeR-bnPN4/maxresdefault.jpg

and 1950, that the next doubling took just 25 years and that by the year 2000, when cropland occupied about 12% of the Earth's ice-free land, the global crop harvest (dominated by cereals) was nearly eight times the value in 1900 (about 2.7 billion tonnes) and that the addition of crop residues (mostly cereal straw) and forage crops (mostly alfalfa) would nearly triple that total. By the year 2015 global harvest of all crops and their residues rose by a third compared to the year 2000. About half of the harvested plant mass is converted by domestic animals into meat, milk and eggs. Annual harvests of woody phytomass (including roundwood, pulpwood, fuelwood and wood directly destroyed or abandoned during harvesting) reached more than 13 billion tonnes in the year 2000 and they were about 10% higher in 2015.

This means that at the beginning of the 21st century we were harvesting about 17% of the global NPP and that by 2015 the share was just above 20%. Given the unequal distribution of heavily cropped and heavily logged areas, this means that in some regions most, or virtually all photosynthetic productivity is destined, directly or indirectly, for human consumption. Moreover, we have been also reducing natural photosynthetic production in ways other than cropping and logging but those impacts are much more difficult to quantify: the most important interferences have been anthropogenic forest and grassland fires, and effects of air pollution and increased global temperature on plant growth and resilience.

Harvesting a fifth, or perhaps even a quarter, of the biosphere's primary productivity may not seem excessive – but let us remember that it is done for the benefit of the single species! Moreover, this 'appropriation' ratio, revealing and important as it may be, does not capture other quantitative, and many qualitative, consequences of ecosystemic and social impacts of expanding plant harvests. There is already plenty of evidence of the enormous scope of the human transformation of the Earth and the future interventions may be further complicated by the unfolding climate change.

I have estimated that once the plant growth reclaimed the higher latitudes after the end of the last Ice Age (less than 12,000 years ago) the global stores of plant mass rose to more than a trillion tonnes of carbon. By 1800 they were reduced by at least a quarter, mainly due to deforestation in temperate zones, and by 2015 the

total was nearly 40% lower than 10,000 years ago, with the recent losses mainly due to tropical deforestation in Latin America, Africa and Southeast Asia. This large loss and impoverishment of habitats led to substantial decline of wild animals: their diversity and total living mass declined as the numbers and masses of domesticated animals rose to unprecedented levels.

My best calculations indicate that in 1900 the living mass of domesticated animals was about three times as large as that of all wild mammals but by the year 2015 the mass of domesticated ruminants (cattle, water buffaloes, sheep, goats), horses, pigs and poultry was at least 25 times larger. The largest wild mammals have suffered particularly large losses, with the mass of elephants now less than 10% of the 1900 level. Perhaps an even more remarkable fact is that in 2015 the anthropomass, the living weight of 7.3 billion people, was second only to the mass of domesticated cattle and that these two species, Bos taurus and Homo sapiens, are now (in terms of total mass) the biosphere's dominant vertebrates, truly the planet of cattle and people (See Image 2 on previous page).

And, as with so many instances of worrisome developments, the worst part of this situation is that it is not going to get better anytime soon. Global population is expected to grow to about 9.6 billion by the year 2050 (equivalent to adding three times Europe's total in 2015, or two Indias), and crop harvests will have to rise even faster if we are to lift more than five billion of people now living in low-income countries closer to the quality of life that is enjoyed by a minority of the global population. A particularly demanding component of this change is to meet the growing demand for meat whose production entails inevitably low-efficiency conversions of plant mass, with feed/lean meat ratio typically at 3-4 for poultry, 7-9 for pigs and well above 20 for beef raised on mixtures of concentrates (grain) and forage.[5]

And, a commonly ignored necessity, the future expansion of food production will require higher energy use, directly as gasoline and diesel fuel for field and crop-processing machinery and irrigation, and indirectly as natural gas, oil, coal and electricity in order to synthesise and process inorganic fertilisers (above all energy-intensive nitrogenous compounds), herbicides, insecticides and fungicides and to breed new crop varieties. My calculations show that during the 20th century, as the world population increased 3.7 times and the harvested cropland expanded by about 40%, energy consumed per unit of agricultural area soared roughly 90 times – while the world's agricultural harvest (measured in overall energy terms) expanded six-fold.[6]

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But further large increases of energy inputs are not inevitable, and food required to meet further population increase and to improve inadequate nutrition could be produced with only relatively small expansion of cultivated land. That is because we use modern agricultural inputs so inefficiently (the two key inputs, irrigation and nitrogen fertilisation are particularly wasteful) and because we waste inexcusably large shares of what we produce (on the order of 30% worldwide, 40% in affluent economies where food is sold too cheaply, encouraging waste). Fixing these losses is challenging but it is also highly rewarding because it would not only save valuable resources but it would help to spare the biosphere and leave more of its primary productivity for millions of other species with whom we share the planet.

## About the Author

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