CALCULATING EARTH OVERSHOOT DAY 2020:
ESTIMATES POINT TO AUGUST 22ND

1. CALCULATING EARTH OVERSHOOT DAY BEFORE COVID-19

Earth Overshoot Day is the day of the year on which humanity's demand on nature exceeds the Earth's capacity to regenerate this demand over the course of the entire year. In 2020, Earth Overshoot Day will fall on August 22nd, meaning that between January 1st and August 22nd, humanity will have demanded an amount equivalent to what the planet can regenerate over the whole calendar year, given best available data.

This report outlines how the date of Earth Overshoot Day was calculated. To determine Earth Overshoot Day, one needs to calculate the ratio between the Earth's ability to generate resources, or its *biocapacity*, and humanity's demands placed upon nature, its *Ecological Footprint*.

All demands on nature compete for biocapacity: sequestration capacity for CO_2 from fossil fuel combustion, demand for food and fiber, energy production (from hydropower to biomass), space for roads and shelters, etc.

Both biocapacity and Ecological Footprint can be tracked and compared against each other, based on two simple principles: (1) all the competing demands on productive surfaces, i.e., the surfaces that contain the planet's biocapacity, can be added up; (2) by scaling these areas proportional to their biological productivity, they become commensurable. The measurement unit used is "global hectare" which is a biologically productive hectare with world-average productivity.

More details about the principles and mechanics of this accounting system are documented extensively in the literature and on Global Footprint Network's website. An overview of the principles is available in this open-access paper.

Calculations for countries and the world as a whole are done through the National Footprint and Biocapacity Accounts, based on 15,000 data points per country per year, all from UN statistics. The newest accounts (2019 edition) reach from 1961 to 2016 (the 2020 edition is scheduled for late August 2020.) UN data comes generally with a three-year lag. A good introduction to the National Footprint and Biocapacity Accounts and recent improvements are available in this open-access paper.

To estimate the actual Ecological Footprint to biocapacity ratio for 2020, we now-casted the assessment using newer data points from other sources as well as extrapolation.

The details of the assessment are explained in this report.

Typically, such now-casting is simpler, as trends do not shift radically in typical years. Our typical approach combines more recent data points on carbon emissions, population, and other resource uses, with mathematical extrapolations of data series using an Exponential Triple Smoothing (Forecast.ETS) algorithm. This year, however, the COVID-19 pandemic has caused shifts in resource demand to be far more radical, requiring more detailed research, while still producing a less robust now-cast than in ordinary years.

For this task, we were guided by the research question "by which date in 2020 will humanity's demand on nature, from January 1st to that date, be as much as the Earth's ecosystems can renew in the entire year?" That date is Earth Overshoot Day. This report lays out the data and underlying assumptions that led to the conclusion that Earth Overshoot Day 2020 falls on August 22nd.

2. 2020 Changes to Ecological Footprint

Several elements of the Ecological Footprint need to be updated to reflect the reality under COVID-19: Carbon dioxide emissions from fossil fuel use, which currently make up the majority of humanity's Footprint, have dropped substantially, as have rates of logging for timber. This section outlines the areas we investigated to assess change in:

1. Carbon emissions
2. Food Footprint
3. Forest products Footprint
4. Other domains.

All of those effects have been factored into the Earth Overshoot Day calculation.

2.1 Change in Carbon Footprint: 14.5% Reduction

In 2016, carbon emissions from fossil fuel use made up about 60% of humanity's Ecological Footprint. Fossil fuel is still by far the dominant source for commercial energy, whose use has also been strongly affected by the lockdowns in many countries around the world. The proliferation of lockdowns and associated public health measures have affected almost every sector of the global economy.

Researchers from the University of East Anglia provide a sectoral breakdown of the effects of confinement policies on CO_2 emissions in their May 19 paper titled "Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement." They combine a variety of data sources, including the mobility data that tech giants Apple and Google have made public, to quantify the expected drop in emissions for sectors including transport, power, industry, aviation, and residential use. The paper argues that at their peak, confinement measures resulted in a worldwide 17% daily reduction in emissions, leading to a potential annual emission reduction of between 4.2% and 7.5% compared to the year prior.

Many other institutions have also been performing valuable analysis: Estimates of the drop in 2020's emissions relative to 2019 have come from UK-based organization Carbon Brief as well as the International Energy Agency, whose 2020 Global Energy Review anticipates an 8% decline in emissions. The Global Energy Review also includes analysis of the reduction in national energy consumption by type of lockdown in place: full lockdowns (stay-at-home orders), partial lockdowns (curfews, closures of non-essential businesses), or limited measures (school closures, bans on public gatherings). The analysis from the International Energy Agency forms the basis of Global Footprint Network's 'COVID-19 carbon-adjustment' to Earth Overshoot Day. Because the IEA's analysis of energy includes all fossil fuels, not just those used in electricity generation, we are confident that it captures the majority of emission sources.

Quantifying the Decrease in Carbon Emissions

Our adjustment consists of defining a percentage reduction in CO_2 emissions relative to 2019 and applying that adjustment on top of the usual forecasting functions. Since Earth Overshoot Day is defined as the day when humanity's Ecological

Footprint overtakes the earth's yearly generation of biocapacity, we are therefore limited to factoring in only the decline in emissions from January 1st to Earth Overshoot Day. The only portion we have to forecast is the time period from the time that our research was completed (end of May) up to Earth Overshoot Day (late August). Beyond May, as we outline below, we expect the gradual easing of lockdowns around the world.

To determine the COVID-19 carbon adjustment, the pre-Overshoot Day period was divided into three segments: January-March, for which the IEA has already released an analysis of energy and emissions reductions; April-May, representing the most severe periods of lockdown; and June-'Earth Overshoot Day', when we expect to see a gradual loosening of confinement policies. Combining an understanding of the effect of different forms of lockdowns on energy consumption (Table 1) and the distribution of lockdowns (Figure 1) allows us to develop an estimate of the decline in energy consumption: 9.5%.

TABLE 1.

Form of lockdown	Approximate decline in energy consumption relative to 2019
No lockdown	0%
Limited measures	-8%
Partial lockdown	-17%
Full lockdown	-25%

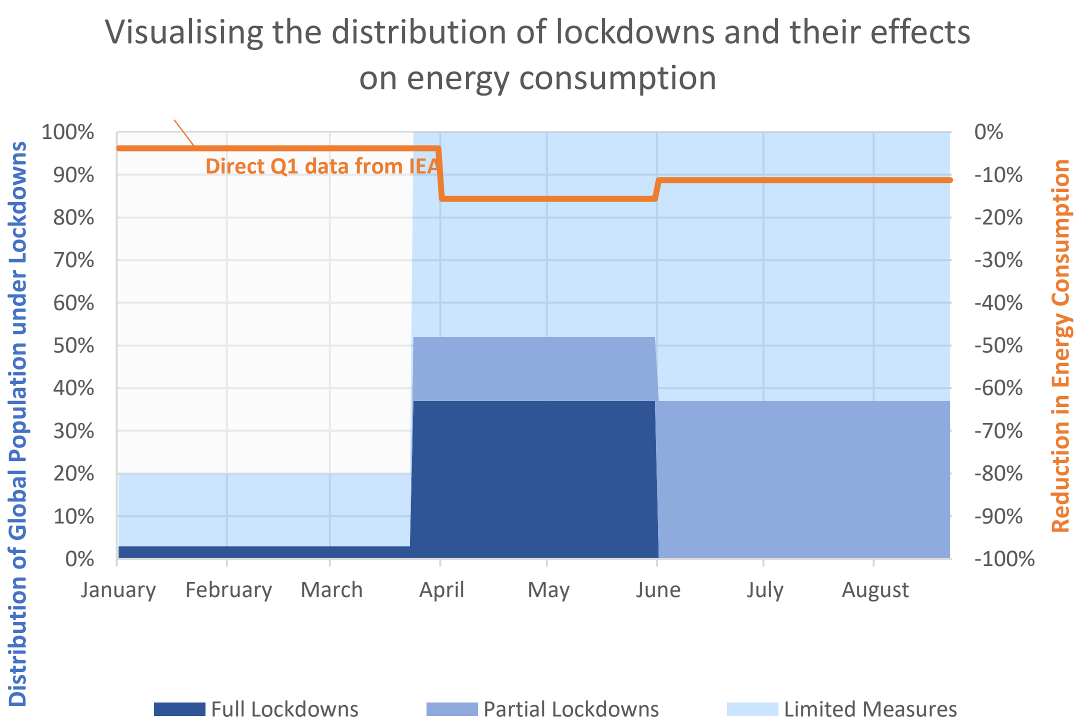

Figure 1.

The fact that the calculation process involves Earth Overshoot Day itself as an endpoint means that determining the date involved an iterative process. Earth Overshoot Day 2019 was used as a starting point to estimate the pre-Overshoot Day decline in CO_2 emissions, allowing a new Earth Overshoot Day to be calculated. The process was repeated multiple times until it converged on a date.

The final step in the process involved converting the estimated decline in energy consumption to a decline in emissions. Energy and emissions do not follow a direct 1:1 relationship: when energy demand declines, high-polluting energy sources get phased out of the energy mix before renewables do. This is because renewables have relatively few ongoing costs beyond the initial capital investment, whereas traditional coal or gas power plants feature continuing fuel costs. Data from the International Energy Agency for the first three months of 2020 showed that a 3.8% drop in energy consumption was associated with a 5% drop in emissions. Assuming that this marginal relationship holds for greater declines in energy consumption, we can expect a decline in emissions of 12.5% for the pre-Overshoot Day period.

To translate this drop in carbon emissions into a change in carbon Footprint, this number needs to be put in the context of the entire carbon cycle, including sequestration by oceans and emissions from land-use change such as the conversion of forest to agricultural land. This combined effect lead to a 14.5% reduction of the carbon Footprint.

Details are available in the associated calculation sheet available upon request.

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2.2 Forest Products Footprint: 8.4% Reduction

The demand for forest products makes up a significant part of humanity's Ecological Footprint, and demand has been directly affected by the COVID-19 pandemic. Currently forest products make up 10% of the Ecological Footprint. Two opposing effects appear to influence this demand.

Effect 1: Reduced demand for Forest Products due to economic slowdown

Activity in the logging industry has declined in recent months, both because of the general reduction in economic activity observed during lockdowns and because of projections indicating diminished demand for construction materials during the coming economic downturn.

Developing a quantitative estimate of reduced demand:

One key data point comes from the Canadian forest industry which reports that the lumber harvest is being reduced by approximately 60% compared to the year prior (CFI, 23 Mar 2020; Greene, 26 Mar 2020; WestFraser, 3 Apr 2020). As indicated in the aforementioned references, this may also affect pulp production. However, we assume that paper demand will not be impacted as much as lumber given the large percentage used for sanitary applications. Hence we apply the reduction only to the lumber part of the timber harvest. If we assume that the Canadian forest industry is broadly representative of global trends, we can estimate a decline in global forest product Footprint due to COVID-19. A 60% decrease in the harvest of timber products for lumber[1] starting shortly after lockdown[2] results in a 9.9% drop in the forest product footprint compared to the same period in 2019.

Effect 2: Increased Pressure on forests from COVID-19-induced internal migration

On the other hand, countries with limited social safety nets often see migration from urban to rural areas during economic downturns (Elliott, 2011). People who lose work in the cities often return to communities located in rural areas with a significant forest interface, accelerating deforestation through increased pressure from local agriculture and resource extraction (Reuters, 22 May 2020). The pandemic has additionally restricted conservation efforts and reduced conservation policing in at-risk areas, both in the Amazon (Mongabay, 18 May 2020) and Southeast Asia (Reuters, 26 Mar 2020).

Developing a quantitative estimate of increased pressure:

To develop an estimate of the pandemic's impact, we first used data from Brazil's National Institute for Space Research (INPE, 8 May 2020) which uses satellite monitoring to track rates of deforestation in the Amazon. INPE reports that in the first four months of 2020, deforestation in the Amazon is up 55% from a year ago, to 1 202 km^2 (INPE, 8 May 2020).

We compared these values to data from the Sinchi Institute, whose terrestrial environmental information system reported 12 958 heat spots – forest-clearing fires – during the month of March 2020, compared to 4 691 in March 2019. This 176% increase represents a near-tripling of forest clearing under pandemic conditions (Sinchi, 8 April 2020). Assuming an average of 3 ha per heat spot, as estimated by Tansey et al. (2008), would suggest an area of 3 x 12 958 spots / 100 ha/km^2 = 387 km^2 of deforestation per month, or 1556 km^2 over 4 months, roughly confirming the INEP assessment.

[1] Approximately 64% of the of the global forest products Footprint comes from timber products while the remainder comes from wood fuel (Global Footprint Network, 2019.)

[2] We assume reduced harvest period to begin on April 15th 2020.

If we assume 5 months of lockdown during the relevant study period (January 1st to Earth Overshoot Day), we can use these values to estimate the area of additional forest clearance observed under the pandemic conditions in the Amazon:

> **300.5 km^2** (INPE, 2020 monthly deforestation) **x 5 months x 0.5** (proportion of 2020 deforestation attributed to COVID-induced clearing, based on INPE and Sinchi analyses) **= 751 km^2 more deforestation under COVID-19 conditions.**

Converted into the Ecological Footprint unit of Global Hectares:

> **751 km^2 x 100 ha/km2 x 50 years of regeneration x 1.28** (forest EqF) **x 2.1** (Brazilian forest Yield Factor) **= 10.1 million gha more forest product footprint under COVID-19 conditions.**

Finally, because these values are specific to the Amazon, we needed to generalize these values to the whole planet. A new report from WWF Germany comparing COVID-19 related deforestation rates across the tropical world indicates that the Amazon accounts for 32% of global tropical deforestation under COVID-19. Assuming that the deforestation in the Amazon is representative of deforestation across the tropical world, we estimate that COVID-19 resulted in **31.9 million gha of additional forest products Footprint** or a 1.5% increase in the forest products Footprint.

Combining these forest product effects

When the two effects are combined, it becomes clear that the first effect – a decrease in industrial logging due to national lockdowns and global economic slowdown – is the most significant. Overall, we estimate that the pandemic resulted in an 8.4% decrease in forest products Footprint.

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2.3 Food & Agricultural Footprint

The COVID-19 pandemic has significantly impacted the food system, but overall, it is not clear whether it has changed the food Footprint. We assume it has not.

With the closing down of many food preparation facilities (such as canteens, schools, restaurants and bars), even people in higher-income countries are now mostly eating at home. On the household and consumption side, food waste is probably decreased (NIH1); this is because home consumption is typically more efficient as people can choose their portions, and leftovers can be stored and reused easily.

However, on the production side, the COVID-19 pandemic has revealed the extraordinary brittleness of our food systems. In higher-income countries, supply chains were not able to react to the disruption of the lockdown, leading to enormous waste (NYT1). Food has not been harvested and the logistics of distribution have become more difficult. Farm workers have not been able to be deployed, especially workers from abroad due to border closures, leaving food unharvested and fields unattended (WEF1). Similarly, cross-border supply chains have become more vulnerable.

Meat and fish processing plants seem to be particularly vulnerable for a variety of reasons (Wired). Like other congregate living and working facilities, they seem to be hotspots for transmission, making it dangerous for workers and reducing the capacity to deliver animal products to people.

According to our preliminary analysis, the resulting outcome is that the Footprint has remained unchanged on the production side – the difference in reduced demand has just become waste. Although the overall food Footprint may not have changed, the pandemic and accompanying disruption to the global food system has still put many people at risk. This is particularly true for small holder farmers, whether in West Africa, India, or Latin America. They are not able to get inputs such as animal feed, fertilizer, or pesticide, and cannot get their products to market. Distribution from farm to fork is being disrupted, and many lower-income populations have lost their jobs and therefore their ability to purchase the food they require (WEF1). The lockdown has even impeded the fight against the locust infestations from Sudan all the way to India (BBC).

The World Food Program estimates that hundreds of millions of people have been driven into poverty (WFP, Sumner, Economist, NYT2). This extreme poverty means extreme food insecurity: some not getting enough food, others not getting a complete, nutritious diet (WEF2). This is particularly important for mothers and young children as nutrition between conception and the 2nd year of birth is particularly critical for full development [WHO].

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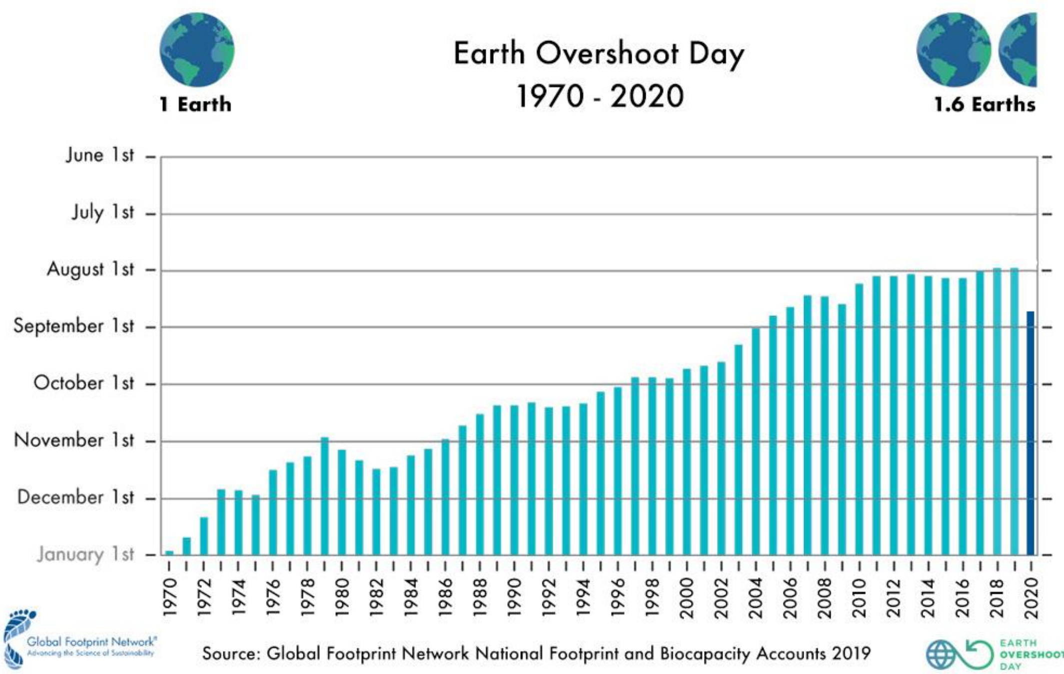
2.4 Other Footprint and Biocapacity effects

As we extrapolate from absolute biocapacity and Footprint, the population numbers do not play strongly into the estimates as they do not directly appear in the accounts (the ratio of absolute Footprint to absolute biocapacity is the same as the ratio between per person Footprint and per person biocapacity). It is not yet clear how COVID-19 has affected overall mortality and natality (a smaller population would lead typically to a smaller demand.) There are some indications that fish consumption is down, but no reliable data could be found. Biocapacity may have changed as well, due to locust invasions or labor shortages in agriculture. At this point in time, however, no relevant data is available to substantiate the significance for global biocapacity.

As a result, we assume no significant Footprint or biocapacity impacts other than the ones outlined in sections 2.1 through 2.3.

3. 2020 Earth Overshoot Day: August 22nd

Given all the recent trends, including the impact of COVID-19, our calculations explained above (and in the calculation spreadsheet available upon request) conclude that Earth Overshoot Day 2020 will fall on August 22nd. Last year's Earth Overshoot Day, in contrast, was on July 29th.[3] This shift in the year-to year date of Earth Overshoot Day represents the greatest ever single-year shift since the beginning of global overshoot in the early 1970s. In several instances the date was pushed back temporarily, such as in the aftermath of the post-2008 Great Recession, but the general trend remains that of a consistent upward trajectory.



[3] Note: as we also have recalculated past Earth Overshoot Day, given more complete data, 2019's Earth Overshoot Day we now estimate to have been on July 31 rather than 29th. This is a reflection of better data, not a shift in calculation methodology.

4. Sensitivity Analysis

There are several sources of uncertainty which potentially affect the calculations for Earth Overshoot Day. These can be categorized as systematic errors, which consistently under/overestimate figures, and relative errors, which vary from year to year.

Systematic errors which could potentially affect the date of Earth Overshoot Day are suspected to exist in the National Footprint and Biocapacity Accounts used to calculate global Ecological Footprint and biocapacity. Data is obtained directly from the United Nations and does not include margins of error or confidence scores. However, we suspect that Ecological Footprints are likely to be underestimated and biocapacity is likely to be overestimated. This means that global overshoot is most likely larger. While Ecological Footprint and biocapacity numbers are probably systematically under- and over-reported, respectively, the National Footprint and Biocapacity Accounts do so consistently, meaning that the trends are reliable.

Potential sources of relative error involve issues with stocks and flows: Resource extraction and resource consumption are not necessarily the same. For example, oil extraction is well documented, but it is not clear how much is being used and how much is going into stockpiles. The functions used to extrapolate Ecological Footprint and biocapacity to 2020 also present an additional source of uncertainty.

When it comes to the adjustments made to account for COVID-19, sources of uncertainty can be found in three places: the International Energy Agency's estimates of energy decline according to the severity of lockdown measures; uncertainty about whether the marginal relationship between declines in energy demand and emissions observed in Q1 holds for larger declines; and the assumptions made about the future distribution of lockdowns around the world.

Also, the forest estimates are based on best data available at the time of calculation. We may also later find that the food Footprint did shift and that COVID-19 also had an impact on biocapacity and population size. The UN data-based National Footprint and Biocapacity Accounts might only be able to show the effect by their 2023 edition, but it may be possible to make more informed estimates before that date.

5. For further information

This research report and the underlying calculations were produced by Dr. David Lin, Leopold Wambersie MSc, Dr. Mathis Wackernagel, and Prof. Pat Hanscom at Global Footprint Network.

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