How much of the Earth's vegetative biomass is due to human civilization?

The majority of the world's land has been wilderness until very recently. However, over the past few centuries, Earth's landscapes have undergone a dramatic transformation as a result of human activity: wild habitats are continually being converted for agricultural purposes.

This land use has only been accelerating, due to rapid population growth and increasing food requirements, as shown in Figure 1. 1000 years ago it's estimated that less than 4% of the world's habitable land had been domesticated for farming. Today, that percentage is roughly **12x as large.**

This drastic human impact on our environment is significant to quantify for many reasons. Of course, it has transformed wildlife habitats, and is therefore one of the greatest threats to our planet's biodiversity. Of the 28,000 species currently threatened with extinction, 'agriculture' is listed as a threat for 24,000 of them. Additionally, land use practices can encourage the spread of invasive species, further threatening biodiversity. Conversion, fertilization, introduction of livestock, and use of chemicals are only a few of the cultivation practices that not only enhance the growth of invasive plants, but also reduce the quality and availability of resources for native species.

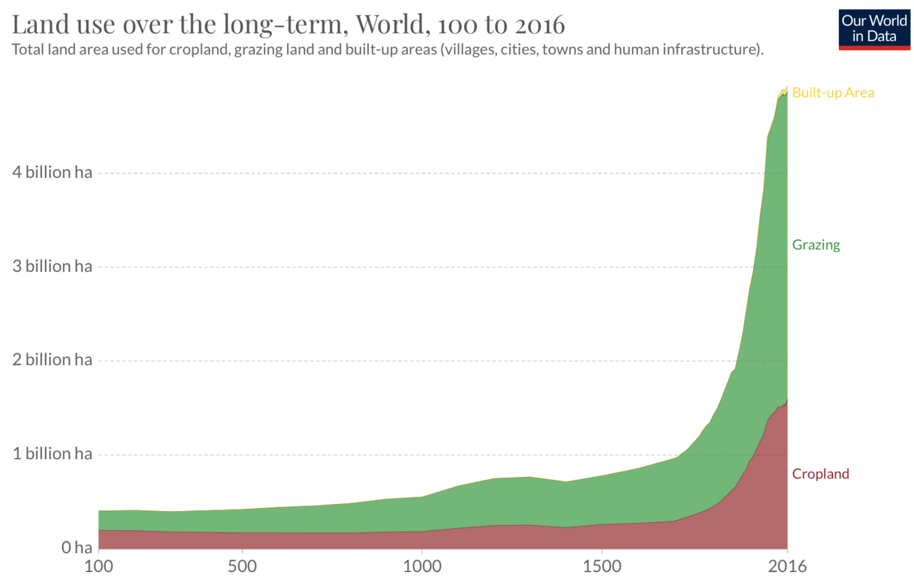

Fig. 1

Agricultural land use can even pose risks to human life: the runoff from pesticides, fertilizers and other chemical can degrade our water quality, and increased wind erosion and dust from loss of habitat can over-expose humans to particulate matter and chemicals. Some studies even indicate the spread of vector-borne disease may be exacerbated by land use and similar environmental changes.

We are interested in characterizing this drastic shift in our landscapes by the resulting change in global vegetation. Specifically, **we can quantitatively estimate the human impact by the ratio of cultivated vegetation to wild vegetation** (both measured in biomass) present on Earth to date. In order to do this, we needed data on the habitable land areas on Earth (measured in square kilometers) and the average vegetative biomass of those regions (measured in tons of Carbon per square kilometer). The land area data was easily obtained from the U.N. Food and Agriculture Organization, as illustrated in Figure 2. The biomass data was not as straightforward to obtain, as the average biomass of a region depends on the type of ecosystem present— forest, grassland, etc. —thus, our approach had to be altered to take this variation into account. Fortunately, the UNH/CU/GLOBE Global Biome Table presented the mean plant carbon storage for every type of habitable biome, providing our biomass data in Figure 3. Both data sources are fairly well-established organizations, and unrelated studies agree well with their figures.

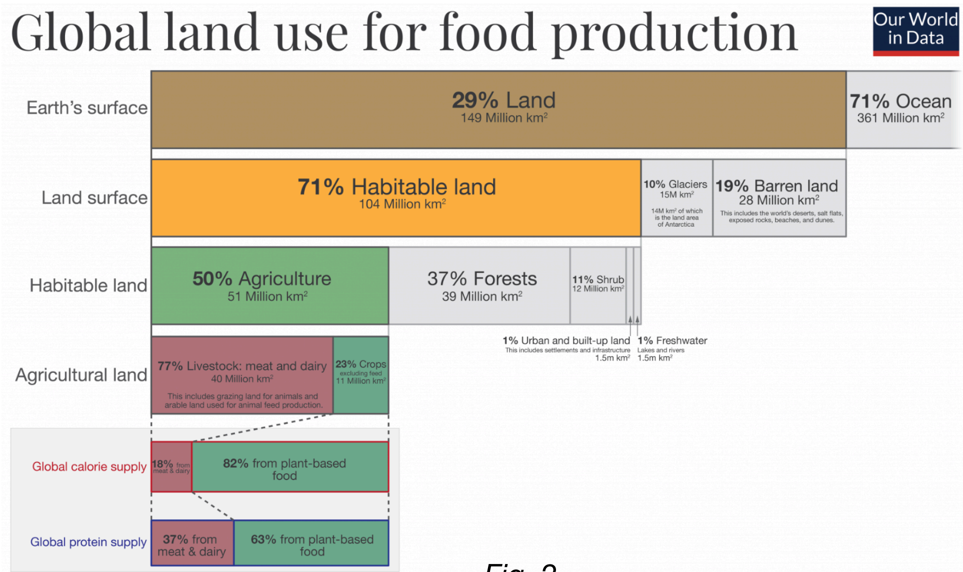

Fig. 2

The numbers tell us that roughly 50% of habitable land has been developed for agricultural purposes, and the other 50% has remained wild. At first glance, then, we might assume that our ratio will end up close to 1. But again, we need to take into account the variation of biomes across the two land categories.

Agricultural land is allocated to two main things: grassland and cropland. It's estimated that roughly 60% of cultivated land is converted grassland (for livestock to graze on), and the remaining 40% is cropland.

From our biome table, we can approximate that the average biomass* for grazing land is 770 tC/square km, and 1000 tC/square km for cropland. Multiplying these agricultural biomass estimates by the land areas they occupy, and summing them together, we obtain a total of **4.4 x 10^10 tons of Carbon for the total biomass due to cultivated greenery.**

Global Biome Table

The Carbon Component of Primary Production and Biomass for the Biosphere

(adapted from Whittaker and Likens 1973)

Ecosystem Type	Area ($10^{12}m^2$)	Total Plant Carbon (Pg C)	Mean Plant Biomass (g/m^2)	Mean Plant Carbon Storage (gC/m^2)
Boreal forest	12	108	18000	9000
Cultivated land	14	7	1000	500

Fig. 3

Wild land, on the other hand, is comprised of forests, scrublands, and natural grasslands. From Figure 2 we can see the breakdown is 37% forests, 11% scrublands and grasslands, and approximately 1% freshwater lakes and rivers (which will not be included in this estimate). Using the global biome table again, it was determined that the average biomass* across forests was 16,400 tC/square km, scrublands was 1000 tC/square km, and grasslands was 1000 tC/square km. Again, multiplying these biomasses by their respective land areas, then summing, gives us a total of **6.6 x 10^11 tons of Carbon for the total biomass due to wild greenery.**

Finally, after dividing these two totals by each other, we've arrived at our human impact number: **0.07**

This estimate seems reasonable due to the relative sizes and masses of the two dominant biomes in the cultivated and wild categories: grasslands vs. forests. This is because although the total cultivated and wild land areas are roughly equal, their average biomasses are wildly different: after all, no one's cultivating forests. Therefore we can see that despite using approximately 50% of all habitable land for sustaining human life, the impact we've made on Earth's greenery is relatively small. However, for such a short timespan, it's a nontrivial figure. And if we continue using land at an exponential rate, this number will only get much larger, causing permanent damage to Earth's ecosystems, biodiversity, and ourselves.

** In cases where a biome category (e.g. forests) consisted of more than one type of ecosystem (e.g. temperate, tropical, etc.) the average biomass was calculated by taking the mean of the mean plant carbon storage across all types of ecosystems within that biome. A more precise estimate could likely be done using a weighted mean by area.*