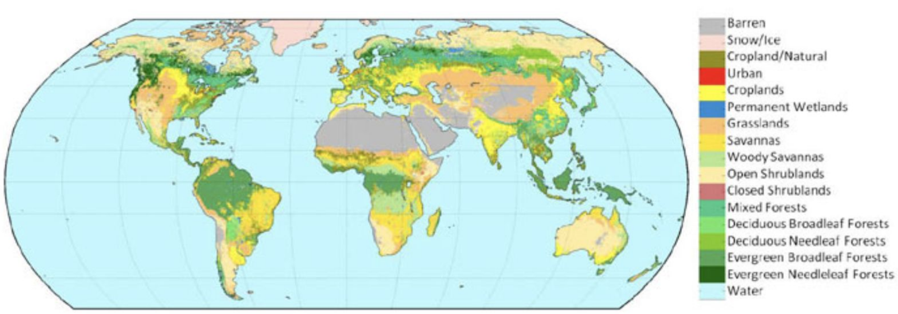
<u>How much land is used by humans?</u> - Cathy Miao, APh 150, 2020

Significance

The Terra Number represents the proportion of land used by humans to the total land on Earth. Accurately determining this number is practically important since total land and resources are limited, which makes efficiency and sustainability in land-use planning crucial to maintain our presence on the planet. This requires being able to efficiently allocate land use to meet current needs, and to do so in a way that does not detriment future generations with regards to resources. Additionally, the conservation of natural ecosystems and habitats and the reduction of pollutants contributing to global warming and low air quality are important factors to think about with regards to how overall land should be distributed. In the following text, we discuss current data and determine the value of the Terra Number, before concluding with our assessment of the overall human impact.

Data

There are different ways to approach the problem of determining global land use percentages. One method is to create global land use maps using pixel wise image classification techniques on satellite data. This approach is limited by the accuracy of the image classification portion, as well as the resolution of the satellite imagery itself. One dataset that uses this method to create a global land use map is the 0.5 km MODIS-based Global Land Cover Climatology dataset by University of Arizona scientists (fig. 1). Another method to determine global land use is to leverage self-reporting, however this approach is primarily limited by biases or human error in measuring or reporting land use. The UN Food and Agriculture Organization (FAO) utilized this self-reporting method, taking information from questionnaires, in addition to other sources such as data released from government web portals, to create an estimate of global land use[2] (fig. 2).



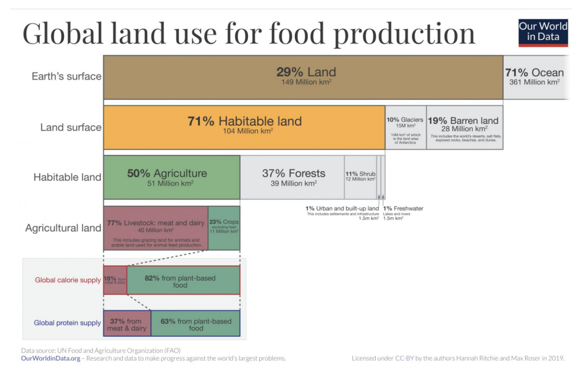


Fig 1: Global land use map based on satellite data[1]

Fig 2: Global land use division based on self-reporting[3]

Upon closer inspection, these 2 datasets differ greatly. We perform pixel classification on the satellite data-created land use map to determine corresponding frequencies of land use (fig. 3). One large discrepancy is that the satellite-produced global land use map has 7% of total land being classified as "croplands", while the FAO data classifies 35% of all land as used for "agriculture". This is likely due to image classification on satellite imagery being more precise with regard to natural land cover, as can be seen with 13 of the 17 classification categories given as different forms of natural land cover (the remaining 4 are: barren, urban, croplands, and water). This may be due to a limitation in land coloration being usable to distinguish human-influenced areas. In addition, the classification of "croplands" does not encompass pastureland, which comprises a significant portion of agricultural land in many countries. This discrepancy is clear when we inspect Australia, where the FAO data estimates that 53% of Australian land is used for agriculture, while the MODIS data classifies the large majority of Australian land as "open shrublands". When we compare with a third source (the Australian Bureau of Statistics), we see that the reported total agricultural land percentage is 51%, which is much more consistent with FAO data[4]. For these reasons, we decide to use the FAO data for our calculation for the estimate of the Terra Number, to which we get a value of 0.36 (fig. 4).

Reasonability

To measure the reasonability of the data, and by extension our calculation of the Terra Number, we perform an order of magnitude estimation to compute the total land used for agriculture, a large portion of total human land use. To do this, we estimate the amount of food consumed by an individual, which we guess to be ~2kg per day, with 50% coming from meat and animal-based products and 50% from plants. We get the land productivity of plants from crop yield data to estimate the land required for plant consumption. We estimate that the land productivity of meat is 10% of that for plants, by the law that estimates 10% energy transfer from a lower trophic level to a higher one, to get the corresponding value for meat consumption. We finally estimate the total agricultural land required to sustain the human population of ~8 billion people, which we get to be 30 million km^2 (fig 5). This is consistent with the data, which has the value to be 51 million km^2. We can thus conclude that the data is reasonable.

cluster	pixels	name	HEX	RGB
	39.92%	189,246,254 pale sky blue ΔE=0.9	#BDF5FC	189 245 252
	19.00%	255,255,255 alabaster ΔE=0.0	#FFFFFF	255 255 255
	6.09%	253,253,254 pale grey ΔE=0.4	#FBFBFB	251 251 251
	5.35%	183,182,181 triple concrete ΔE=1.0	#B7B8B6	183 184 182
	3.24%	74,168,85 moderate emerald green ΔE=3.4	#56AB5A	86 171 90
	2.83%	173,217,209 scandal ΔE=1.0	#AEDCD3	174 220 211
	2.70%	221,214,24 piss yellow ΔE=2.9	#E6DF28	230 223 40
	2.58%	159,191,194 chi ΔE=1.0	#A0C1C3	160 193 195
	2.46%	236,224,144 wild rice ΔE=2.3	#F3E698	243 230 152
	2.43%	209,209,209 grey ΔE=0.2	#D2D2D2	210 210 210
	2.17%	177,210,123 pale olive green ΔE=2.8	#B0CF72	176 207 114
	2.16%	164,198,57 android green ΔE=4.1	#9BC63A	155 198 58
	2.03%	243,199,98 bardot ΔE=3.5	#E9C061	233 192 97
	1.81%	232,232,232 grey ΔE=0.0	#E8E8E8	232 232 232
	1.54%	203,211,176 green mist ΔE=2.0	#C5D0AB	197 208 171
	1.47%	123,177,141 bay leaf ΔE=3.6	#85BA92	133 186 146
	1.32%	228,207,153 double colonial white ΔE=3.8	#D8CA91	216 202 145
	0.64%	235,185,179 beauty bush ΔE=2.6	#EFBDB3	239 189 179
	0.15%	254,39,18 red ΔE=3.1	#F72306	247 35 6
	0.12%	14,135,204 water blue ΔE=4.0	#378CCD	55 140 205

IMAGE CLUSTER PARTITIONS
Pixels of the image assigned to each cluster. The border is the color of the cluster as calculated by the average value of its pixels.

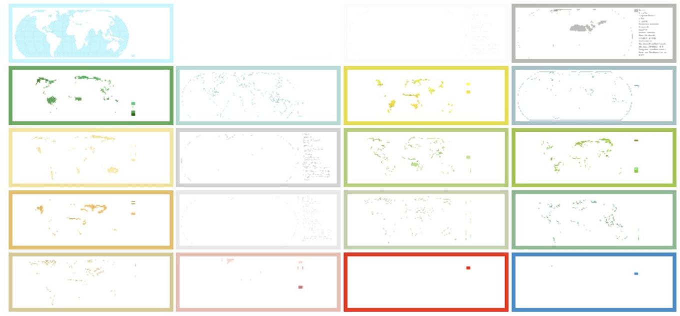


Fig 3: Satellite land use map pixel classification[5]

Total land on Earth[2]: 147.5 million km^2

Total glacier / barren land[2]: 43 million km^2
Total forest / shrub land[2]: 51 million km^2
Total agricultural land[2]: 51 million km^2
Total urban / built up land[2]: 1.5 million km^2

Total land use by humans:
(Total agricultural land) + (Total urban / built up land)
= 1.5 million km^2 + 51 million km^2
= **52.5 million km^2**

Terra Number:
= (Total land use by humans) / (Total land on Earth)
= 52.5 million km^2 / 147.5 million km^2
= **0.36**

Fig. 4: Terra Number Calculation

Total human population[6]: 8e12 people
Human daily diet: 1 kg meat/day, 1 kg plants/day
Plant land use[2]: 10 tons/hectare/yr → **1e6 kg/km^2/yr**
Meat land use: 1 ton/hectare/yr → **1e5 kg/km^2/yr**

Land required for an individual's plant consumption:
(annual individual plant consumption) / (annual plant land productivity)
= [(1 kg plants/day) * (365 days/year)] * [(1 km^2yr) / (1e6 kg plants)]
= **365e-6 km^2**

Land required for an individual's meat consumption:
(annual individual meat consumption) / (annual meat land productivity)
= [(1 kg plants/day) * (365 days/year)] * [(1 km^2yr) / (1e5 kg plants)]
= **365e-5 km^2**

Total agricultural land required to sustain human population:
(population) * [(land for individual plant consumption) + (land for individual meat consumption)]
= (8e12 people) * (365e-6 km^2 + 365e-5 km^2)
= **30 million km^2**

Fig 5: Human food consumption reasonability estimate

Impact

With a current global population of 7.8 billion and the 10 billion milestone expected to be reached in 2056, it makes sense that a large amount of land is used for agriculture[6]. It is also interesting to note that the majority of agricultural land is classified as pastureland, or land used to raise livestock and grow livestock feed. This is because on a per kg basis, livestock requires much more resources, translated here to land, to produce compared to crops grown directly for human consumption. The environmental plant-based eating movement and plant-based meat-imitation products are examples of attempts to address this discrepancy, and reduce the amount of land required to produce food for one person. Actions like this are necessary moving forward, in order to sustainably feed a growing population. From looking at the data, it also becomes apparent that the human impact on land use is enormous, which is detrimental to overall biodiversity and damaging to many ecosystems that haven't had sufficient time to adapt to a human-dominated landscape. It is thus also important to accurately assess and make attempts to preserve natural areas, such as forests and other wilderness areas.

References

1. https://archive.usgs.gov/archive/sites/landcover.usgs.gov/global_climatology.html
2. http://www.fao.org/faostat/en/#data/RL
3. https://ourworldindata.org/land-use
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5. http://mkweb.bcgsc.ca/color-summarizer/?
6. https://yaleglobal.yale.edu/content/world-population-2020-overview