Your patch of earth

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The surface of our planet covers an area of a little more than 50 billion hectares, about 36 billion hectares ocean, and just under 15 billion of land. In late 2011 there were 7 billion people on earth. Dividing the land area by the number of people gives your personal patch of earth - 2.13 hectares, your ocean a little under five and a quarter hectares. Represented by a flat disc, your land would be about 160 metres across, your ocean about 230 metres across.

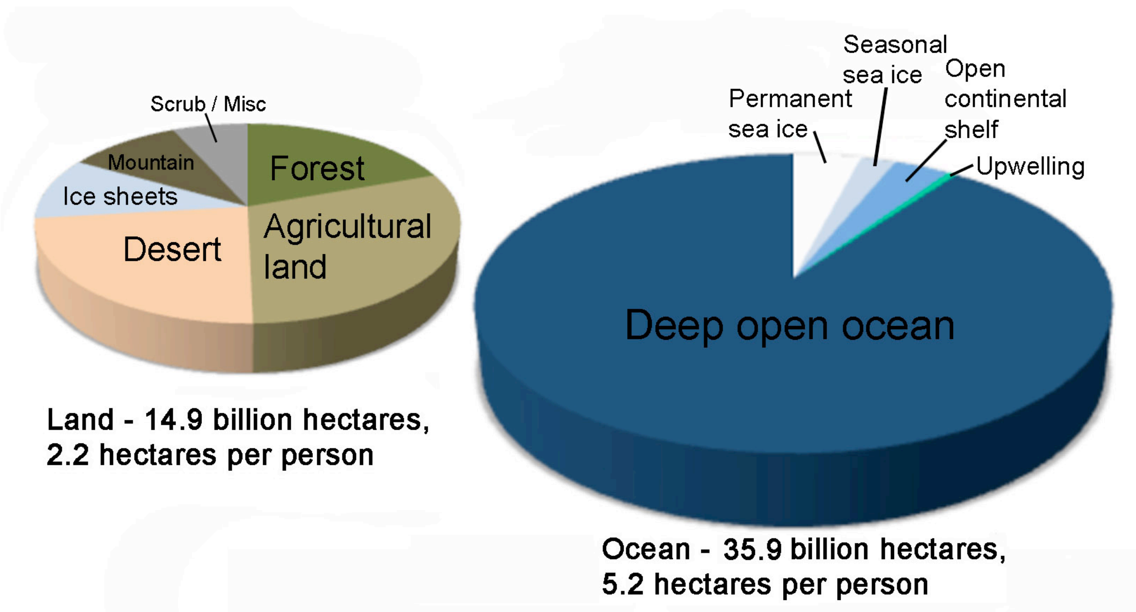

Fig. 1 Breakdown of earth surface area by type of land

We're not evenly spread. India, for example, is particularly crowded, with a little over a quarter of a hectare per person, as is the UK, with around a third of a hectare for each of us. The US sits somewhere close to average, with over two hectares per member of the population, while Canadians have ten times as much space, and particularly rich resources of soils, water, trees and marine life. Australians have a similarly massive patch of land, but made up largely of desert. Greenlanders have 4100 hectares each, but most of this is ice sheet, while personnel on the Antarctic continent have stewardship of ten thousand hectares of ice each.

As an average, though, humans on earth have just over 2 hectares. From your two hectare plot you need to find or grow all your food, your fuel, everything to build your home and everything in it. Here you will spend all your recreational time, and here you will need to process all your waste. You will spend your entire life here.

Thirty years ago you would have had twice as much land – that's how fast human populations have grown. In 1927, when the human population reached 2 billion, it would have been nearly seven and a half hectares, or a disc 308 metres across - over *three times* as much area as we each have today. According to the US census bureau or the UN, around 2027 we will reach 8 billion people, giving us each 1.86 hectares, or a disc of land 152 metres across. And that's the unknown territory we're facing; our share of the world is shrinking fast. In the last couple of decades the planet has been saturated with humans as it's never before been saturated with a large animal, least of all one that demands such resources

How your pie is sliced

So how is your land broken down, and what can you realistically do with its resources?

Roughly a fifth of your land is a forest of about 64 metres by 64 metres, less than half of the original cover. This forest holds a large proportion of your personal carbon store – it held considerably more before the rapid deforestation of the last few decades. When forest and soils are removed, the carbon they are made of is released, either by respiration or burning, as carbon dioxide to the atmosphere, where it adds to the insulating greenhouse effect of an atmosphere already high in carbon dioxide from the burning of fossil fuels.

Most of the remaining 110 tonnes of live biological carbon store on your 2-hectare patch is held in tree trunks and other plant matter in this forest, and much of your 180 tonnes of biological soil carbon is here also. We are tending to clear rather than build these carbon-dense habitats habitats. Removal of the bulk of the forest, peat and other biological carbon stores sends this carbon literally up in smoke - and into the atmosphere. As forests are cleared the nutrients locked into this biological matter have generally been washed into waterways along with fertilizers and other pollutants where they often concentrate to excess, causing eutrophication and dead zones. If we can keep nutrients held in the soil and keep thick humus growth the productivity of the land, from food production and carbon storage perspectives are both enhanced, as is groundwater retention - absorbing potential floodwater and further improving soil productivity.

Some types of land can build huge amounts of carbon into their trees or soil. Most of our high-carbon land is temperate forest, holding between 150 and 350 tonnes of carbon per hectare. One hectare of rainforest can hold up to 400 tonnes of carbon, most of it in the trees, mangrove forest can hold about about the same, but mostly in the soil. A hectare of peat or of New Zealand kauri, or Californian redwood forest might hold a thousand tonnes or more of carbon. The greatest habitat on earth for sequestering carbon is *Eucalyptus regnans* forest from southern Victoria and Tasmania, which can lock down an astonishing 1900 tonnes of carbon per hectare. Genuinely offsetting our few tonnes a year of carbon emissions via forest and soil regrowth is realistic and highly possible.

But, looking at how much land we have, we each only have a tiny area - a few square metres - of each of these ultra-high carbon storing habitats. One of the most important (with the added bonus of building pleasant surroundings) things we are going to need to do much more of to draw down atmospheric carbon is to nourish and grow trees and soils, simply to absorb and hold some of the carbon we have released to the atmosphere and to hold and build thick soil.

At the moment each of us are releasing around a tonne and a half of carbon each year via our burning of fossil fuels from the sedimentary rocks beneath our land. Those living a consumptive western lifestyle, particularly those regularly travelling long-haul, are releasing several times this amount. With attention to what we do with our nutrients and forests, we can absorb much of this, at least in the short term.

Ice, water and wilderness

An eighth of the area of each of our share of earth is Antarctic and Greenland ice sheets, around 45 metres by 45 metres for each of us, but averaging a little over two kilometres thick. So each of us has over four million tonnes of ice in a little under a third of a hectare – the vast majority of our fresh water supply, most of it locked away past the stormy Southern Ocean on the Antarctic continent.

The rest of your fresh water, around 1.8 million tonnes for each of us, is mainly soaked into rock and deep soils as inaccessible groundwater. You still have plenty of relatively accessible water, though, with around 58 thousand tonnes as snow and non-glacial ice, and 18 thousand tonnes in rivers, lakes, and surface soils. Around 300 tonnes of water is locked away by the organisms on your patch, and about the same again floats in the atmosphere above it.

About a ninth of our land (42 metres x 42 metres) is high mountain ranges, another ninth marginal scrubland. A whole quarter of your total is desert. Neither icecap, mountain nor desert can produce much life, no matter what you do to it – so in total about *half* of your 160 metre wide disc is your own personal wasteland. There is little or no soil foundation, and almost no food is contributed by this land, and from the perspective of biological carbon absorption it can - as it stands - soak up almost zero CO_2 or produce significant food. It seems obvious that from both food and carbon perspectives, this land is going to have to be 'enriched' via soil-building in order to both sequester carbon and provide additional food production.

Feeding yourself from your patch of land

A little over a quarter of your land area is potential farmland (64 metres by 64 metres for each of us), although only about a third of this is actually cultivated at the moment. Of the current farmland, about half is used in growing grain, and half for grazing animals. 11 metres by 11 metres is used to produce 110kg of corn for ourselves and our livestock, 18 metres by 18 metres produces a similar amount of rice and about the same again gives us a similar amount of wheat. Taken together, these three crops provide about half our calories and much of the food for our farmed animals - together by far the largest animal biomasses the planet has ever seen. We each consume six kilogrammes of palm oil per year, requiring 5 metres by 5 metres of our land - unfortunately this has meant the clearing of prime rainforest and loss of soil and tree carbon in Indonesia and Malaysia in particular. Six kilogrammes of soy oil does not require the clearance of forest but is less efficient. Soybean and other edible oils require more energy input and several times as much land for the same oil yield as palm oil.

Looking at possibilities for all seven billion of us to enjoy balanced nutrition, for the sake of this discussion we are going to press *all* of the potential agricultural land into service. Fortunately, your patch of farmland naturally produces on average of ten tonnes (total) plant matter per year. Using your best soils, this could yield about three tonnes of *edible* plant matter per year – far more food than you need - *if* you are herbivorous.

With fertilizer and modern agricultural practices, you can increase the food yield of your farmland. Agricultural yields have doubled in the last century, although improvements are becoming more incremental now. If you intensively farm all of your cropland, you might get five tonnes of plant food per year.

However – nothing comes for free. Large-scale, intensive modern agriculture is basically unsustainable ‘mining’ of soil nutrients, which become food, then eventually sewage. As the nutrients are stripped, the soils lose their bulk, which is lost to the atmosphere as yet more CO_2. Additionally, from an efficiency and sustainability perspective, the fossil fuel energy, fertilizer and other resources going into large-scale monoculture (that you would need to extract from your patch of land) vastly exceed the energy yields in the food produced. These same energy-hungry practices are also chemical-hungry, and tend to pollute both the soils and waterways of your small patch of land. Most corn today is genetically modified to be resistant to pesticides - which are then in your soils. Modern intensive farming practices cannot be the answer.

Fortunately, small scale, organic polyculture can give similar or better yields than our current system of intensive monoculture farming, with the added advantages of more food variety, soil regeneration and improvement (and thus atmospheric carbon absorption) as well as a virtual elimination of external energy and cost inputs. If you're careful, you can to keep these yields sustainable. The good news is, then, your land can sustainably produce more than enough food - you don't need to worry about going hungry.

Let's qualify that last statement. We won't be hungry – if our species chooses to be ***mainly*** vegetarian (actually - mainly vegan). If you want to eat meat more than very occasionally, then you'll need to put aside a large amount of your farmland as pasture or for foodmeal. By the basic laws of ecology, growing agricultural animals is inherently five to ten times less efficient than growing plant matter, not only in terms of how much food the same land can produce, but even more so in terms of water – animals are very heavy users of water.

Animal proteins

Leaving aside for now the health costs of a modern agricultural meat and dairy diet, the ecological costs of providing these western staples are high. Milk and eggs yield protein from crops more efficiently than fish, which produces more efficiently than chicken, which in turn converts food to protein two to three times more efficiently than pork. Ruminants and particularly cattle are the least efficient of our common foods at producing protein. For dairy production, if we assume modern organic agricultural practices and breeds on your best pasture, if you put aside a quarter of your agricultural land (one-eighth of a hectare) – will give you a couple of litres of milk a day from the 'one-eighth-of-a-cow' that land will support.

Let's say you put quarter of your agricultural land (ie. an eighth of a hectare) aside for meat production. This means half of your agricultural land is now dedicated to animal proteins. On a global scale giving this option to everyone means pressing *all* of the planet's potential agricultural land into service – tripling current capacity. We can't really afford to do this from a carbon perspective. We need to instead use our sewage and compost to convert a sizeable amount of land to thick-soiled forest, but if we all want to eat some meat every day let's look at the scope for potential meat production.

The sheer ecological scale of our agricultural meat production has grown massively greater than anything in nature - changing the face of earth's terrestrial ecosystems. Currently your patch of land supports 57 kilogrammes of cattle (the only animal species apart from Antarctic krill whose combined biomass exceeds that of humans), about 15 kilos of pork, eight kilos of chickens, six of sheep and goats. Ruminants in particular might need fifteen times their bodyweight in low-quality feed each year. For comparison, the great herds of wild reindeer, wildebeeste and buffalo are measured in the tens of grams per two-hectare patch of land. All the huge herds of wild game animals added together (many of which, by the way, produce leaner (ie. healthier) meat, more efficiently than cattle do) make up barely 3 per cent of the biomass of the cattle on earth. Our domesticated animals and ourselves are, in ecological terms, far greater consumers than anything similar in nature – or anything the planet has ever experienced.

The type of meat you want to eat has a sizeable impact on how much you can grow. Assuming your forage area and dietary supplementation (all sourced from your land, of course) are good, and that your animals grow at the rate of modern, intensively farmed western farm animals, your eighth of a hectare of meat-producing land could allow you about 120 kilogrammes of edible (ie. once you have removed feathers, bones etc.) chicken or 100 kilogrammes of pork or 30 kilogrammes of beef a year.

Being ruminants, cattle and sheep have the unusual ability to effectively digest grass – a natural food covering vast areas of the planet's surface that is unavailable to many animals. However, as our beef habit has expanded we have needed to create new grasslands – we have deliberately created low-quality land that allows soil erosion! In order to support these agricultural animals we have cleared vast tracts of forest – the greatest natural stores of carbon on the surface of the earth.

Carbon balance within your patch of land

Tree biomass and soil humus each hold slightly more carbon than the atmosphere does, and about a *hundred times more* than the amount of carbon released by our fossil fuel-burning activities each year. These two masses of biological material are by far the largest carbon stores over which we can exert an influence. As mentioned, your personal patch of earth has nearly 200 tonnes of living and dead organic carbon in its soils, and another 110 tonnes or so in its trees. These are your major stores of biological matter – certainly big enough to absorb all of our emissions – if we make a focused effort to build them. The slightly fatalistic idea that 'even if we stop all carbon emissions today we are already locked into centuries of a warmer climate' does not take this into account – and is wrong because of it.

If we actively rebuilt humus and high-biomass ecosystems (mainly soils and forest) on a minimum of a third of the 'potential agricultural' land and on some of our marginal 'wasteland', the amount of carbon we add to the atmosphere via fossil fuels can become manageable. Composting any and all organic matter, including particularly sewage, to put the nutrients back into the soil rather than into waterways feeds the soil and helps this process, while trees hold the soil and water together. The nitrogen in compost, sewage and fertilizers could and should be a superb asset to help building biomass into our systems – specifically tree mass and soils. There is a proviso here - in order to properly break down our compost would need to be rather freer of chemical pollutants than it currently is.

Biochar, or slow-burned charcoal, was used centuries ago in pre-Colombian South America to hold nutrients (from sewage, food scraps and the existing soil) in place and to actually build soils where there were naturally poor ones. This terra preta, or 'dark earth' survives nutrient-rich to this day, amongst the thin and washed-out soils of the Amazon. It almost seems too simple a solution, but we can lock down huge amounts of carbon for centuries by using our sewage, our composted food and garden waste, our paper waste and slow-burned charcoal to build long-lasting soil. Your patch of land, with careful attention to soil rebuild via use of compost, composted dry sewage and other nutrients, can probably absorb between 50 and 100 tonnes of carbon, possibly more, as thick, semi-permanent soil. The global average emission of a little over a tonne of carbon per person per year could be absorbed, at the same time as enriching our biosphere.

A wealthy western lifestyle, though, emits between three and ten tonnes of carbon a year for each of us. If everyone on earth was responsible for giving off this much carbon, catching up with our decades of emissions excess would require perhaps twenty to thirty tonnes of biological carbon that your land would need to sequester *each year* – not impossible for a year or so but really hard to sustain. To 'pay' for the expansion of the western lifestyle in this way would require a dedicated effort to re-build grassland to forest, and to build up desert soils to make scrubland.

Garbage disposal

You need to dispose of all of your waste on your land and sea, obviously. Most garbage is either inert of biodegradeable, but plastics deserve special consideration. For each of us around 14.5kg of plastics are produced each year, mostly as shopping bags or drinks bottles. As these don't biodegrade and release toxins unless they are incinerated extremely efficiently, this rapidly-aggregating mass needs to be addressed. Currently most ends up in landfill, although around three kilogrammes is dumped in your patch of ocean each year, and about half a kilogramme of the infamous North Pacific garbage patch is yours, of a total of about 60 kilogrammes of your share of globally accumulated plastic garbage. The reality of plastic in the oceans is far more insidious than a big garbage patch - plastics break down into small particles, releasing toxins and then being eaten by small animals and slowly being ingested into the biomass of the food webs.

Your patch of ocean

As well as a share of the land, we've given ourselves an equal share of the seas. The seas cover three-quarters of the surface of our planet, so you have plenty of sea. Our allowance of the world's oceans comes to a little under five and a quarter hectares of ocean each. This is a disc of ocean 235 metres across, averaging around 3000 metres deep, and your personal pool of seawater weighs around 200 million tonnes.

Oceans as a whole are considerably *less* biologically productive than land. Life in the oceans is, for the most, rather thinly-spread. The vast majority of the world's oceans compare roughly with desert in terms of plantlike matter produced (or carbon absorbed). This gives you a personal yield of about eight tonnes of plantlike (phytoplankton) production a year. Because it is ocean, and because phytoplankton are microscopic and spread over such vast areas, this huge food resource is inherently 'un-farmable' and effectively unuseable by humans, at least directly. To be accessible, the phytoplankton needs to be eaten by tiny herbivores, which themselves need to be eaten by larger animals. On the other hand, all the food the sea produces requires no input from yourself other than in the harvesting.

So we must let this eight tonnes of phytoplankton work its way up the food web before we can use it as food. Unfortunately, due to fairly major losses along the way as a result of digestive inefficiency, heat and energy used by the individual organisms, what ends up being produced each year from our patch of ocean, is roughly;

200 kilos or so of krill or small fry or 'baitfish' (the lowest in the food chain currently fished)

80 kilos of small fish (small plankton-feeders such as anchovies)

5 kilos of small to medium fish, including tropical tuna

half a kilo or so of bluefin tuna, swordfish, shark or other large predators

This cannot all be considered your annual allowance, though – you can only sustainably harvest a small proportion of this amount each year. If you are eating more than about a quarter this amount each year, you are having more than your share. Have another look at how much cold-water tuna you are 'allowed'.

Currently, intensive fishing – which in most cases is clearly eroding stocks of fish at middle and high levels of the food web – is pulling out about 15 kilogrammes of seafood each year from your five hectares of ocean. Another 6 to 8 kilogrammes comes from intensive aquaculture in productive coastal and inland areas – and this is growing fast. Food for most farmed seafood has to come from somewhere, and ecologically, farmed fish are often carnivores – so we'll be tapping into the 200 kilos of krill and baitfish and 80 kilos of small fish mentioned above. Herbivorous fish, such as tilapia, are being farmed with considerably better ecological food-conversion efficiency.

So it may look like we need to curb our fish consumption (and we do), but bear in mind that because of their cold-blooded metabolism, fish are slightly more efficient at converting their food to meat protein than chickens, and far more so than pigs, sheep or cows.

Sea Ice

We also each have about five thousand tonnes of sea ice, two-thirds of which melts around one pole as more forms around the other with the ebb and flow of the seasons each year. In February, when sea ice is at its minimum globally, we each have around 45 metres by 45 of sea ice, and this expands another 32 x 32 metres for the brief maximum in late October, just before the Antarctic sea ice summer melt. In the last ten years, the area of this ice has reduced a little, but in the Arctic at least it is also getting significantly thinner – down to a little over a metre thick on average – so the Arctic sea ice volume has almost certainly ***halved*** in the last few years. Strong sea ice causes a boost in polar plankton productivity - which doesn't just mean increased food production but also increased carbon absorption;

Plankton save the day – for now

From a food perspective your ocean may be struggling to keep up with our demands, but it is still potentially robust from a carbon-absorbing perspective. Your patch of ocean has a trick up its sleeve – a trick that has been helping us out. The small zooplankton – the copepods, krill and other tiny animals – are constantly dumping carbon to the sea floor. This rather useful phenomenon known as the 'biological pump'. These trillions of tiny animals moult their shells in some cases every week or so, and they also tend to defecate when they migrate to deeper water. Zooplankton are messy eaters, and their half-gathered food pellets, as well as their faeces, form clumps or pellets. The clumps of food, faeces and moulted exoskeleton, spread over the area of the earth, amount to a huge amount of carbon drifting to the sea floor. With the depletion of the forest and the soils, plankton, with their constant dumping of these huge amounts of carbon to seafloor sediments, have become an unlikely first line of defence against atmospheric carbon enrichment and climate warming.

It has been seriously suggested – and large scale experiments have been tried – to seed the oceans with iron. Iron fertilization gives the zooplankton a very effective food supplement, which means that they grow more, and pump more carbon to the sea floor. The principle has worked reasonably well experimentally, although a few questions remain as to the permanence of such sequestration – how long the carbon stays out of the atmosphere. I'm not aware that anyone has ever looked at the ecological side effects of such action. If carbon buildup in the atmosphere has anything like the effects that many people are afraid it will, and our consumptive lifestyles continue to grow, then desperate measures like this will certainly be attempted.

Where do we go from here?

Our economy demands ever-increasing growth, and for this we need more workers and more economic consumption. These economic imperatives are why many nations give financial incentives for couples to produce more babies – and why our economic system just crashed. At the same time, the poor world is rapidly catching up with our consumptive and wasteful western lifestyle. This expanding lifestyle and footprint demands far more from the 15 billion hectares of land, and from the 36 billion hectares of ocean, than we currently take.

At the start of the twentieth century there were only two billion of us, we had seven hectares each. Our individual demands were more modest than they now are. Fifteen years from now it is looking likely that we will have, *at most*, one and a half hectares each.

For the last fifty years technological improvements and development have squeezed enough from the planet to take us way beyond the point of ecological sustainability. These improvements have yielded enormous natural and economic wealth, and given us the illusion of plenty. Now, however, we're down to a rather stretched two and-a-bit hectares each. It's time to decide how each of us is going to use them.