Balancing Carbon While Feeding Ourselves

The feeding ecology and carbon balance of seven billion humans

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Everything useful starts with the drawing of small lines, even when it seems futile, even when we know our individual impacts may seem inconsequential. The lines I'm talking about have to do with food and planetary ecosystem balance in our twenty-first century.

A friend (and many like him) believes that our impacts on the oceans are unacceptable. With systematic overfishing clearly pulling down most of the stocks that we exploit from the seas, and demands that exceed the capacity of planetary fish production, he had decided that he could not eat seafood with a clear conscience.

I, on the other hand had decided that, due to the sheer scale of cattle – the most successful form of animal life this planet has ever seen – and the ecological impacts of how we produce them, that I would not eat agricultural red meat. I wanted to work out which of us was on the more sustainable track, knowing from the start that the answer would never be as simple as right or wrong.

Humans – victims of our own success

Humans have become the third most successful animal species on earth in terms of collective biomass. There are over 300 million tonnes of humans on earth. The most succesful, perhaps ironically, are the over 400 million tonnes of cattle we have bred to feed ourselves, and a long way behind in second place are Antarctic krill, with perhaps a shade less than 400 million tonnes in late summer.

Nature has always supported large biomasses of small or vegetarian animals, and much smaller biomasses of large (and/or carnivorous) animals – this is how ecology works. The populations and demands of ourselves and of agricultural animals, though, have grown in the last century to levels where they now almost certainly exceed the scope of any large animal that has ever existed.

At the turn of the twentieth centruy one and a half billion humans were already heavily impacting global ecology. We are now nearly five times as abundant, and our individual demands have increased hugely. A generation ago, even in the west, meat at every meal was a rarity.

Food and Carbon

So let's look at two things; One; how much food planet Earth - on land and at sea – can produce. Two; how does that food production relate to carbon balance and climate change. I started this process by putting together a very simple ecological model – from the starting point of how much life is produced via photosynthesis, over land and sea, each year. The model then makes some estimates of how much food exists at each level of the food web, and how much is eaten and replenished each year.

A great deal of work has been done on planetary carbon budgets and on food budgets. It has been gratifying to note that my calculations seem to match up with population estimates, production estimates and carbon estimates from a wide variety of sources. You can (and I hope you do) argue the details on some of my figures, but I the overall picture is reasonably close to reality.

300 million tonnes of humans eat nearly three billion tonnes of varied food each year. This is by a huge margin the highest-impact feeding ecology the planet has ever seen from an animal. Ecology at this scale can't help but alter the carbon balance between the atmosphere and the biosphere. What we eat, the environments we alter to make way for our food, the fuel we burn to run the processes and the supply chain all encompass a significant proportion of the world's available nutrients and atmospheric-accessible carbon.

Overview – a balancing act

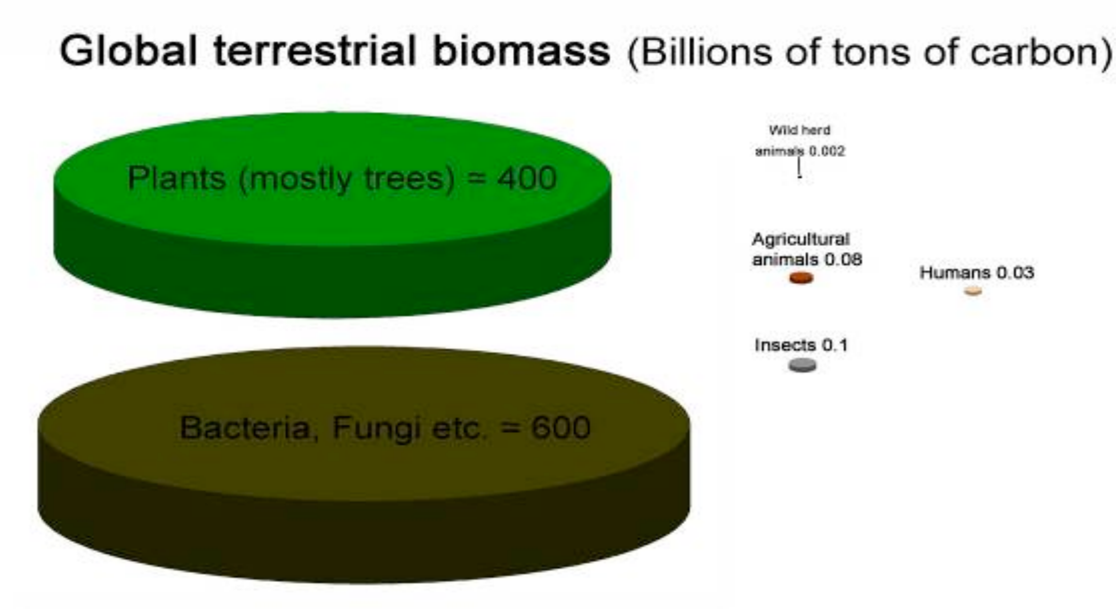
One of the first things to note is that land is considerably more productive than ocean. Per square metre, on average, land draws down more than three times the amount of carbon dioxide from the atmosphere, and converts this carbon dioxide into living, biological matter than the seas do. However, there is three times as much ocean area as there is land area. The end result is that globally, the land draws down about sixty billion tonnes of carbon each year, compared to fifty-odd billion tonnes of carbon for a much bigger area of ocean. Compare this with the ten billion or so tonnes of carbon we release each year by burning fossil fuels.

This combined land and sea primary production pulls out almost a sixth of the entire atmospheric carbon dioxide each year, and converts it to biological molecules. This would deplete the atmosphere of carbon dioxide very quickly (and the planet would rapidly freeze due to the loss of greenhouse insulation), if it wasn't balanced out by something.

The majority of this carbon is returned as carbon dioxide to the atmosphere, mainly via respiration, decomposition and deep water upwelling. A very small proportion of the carbon absorbed and processed via photosynthesis stays 'locked down' as biological matter, but it is variations in this tiny amount year on year - along with our fuel-burning emissions - that affects the global carbon balance.

Carbon balance on land

On land, biological carbon is built over decades into the organisms that make up by far the majority of the living things on the planet; trees and the bacteria and other single-celled and multicellular organisms in the soil humus and other sediments.



The biological component of the soil holds much more bio-available carbon than the atmosphere does, the trees almost as much again. Throughout hundreds of millions of years of prehistory, the luxuriant growth of plant matter, peat and soil has slowly but effectively pulled out the majority of the atmospheric carbon, converting it, ultimately, into carbonate rocks and fossil fuel deposits. This is why we have a life-supporting environment. Soil erosion and any land use changes that reduce tree cover release significant amounts of this carbon to the atmosphere.

We can convert forest to agricultural land in order to feed ourselves, and indeed have already converted perhaps a quarter of our original forest to agriculture or other uses, according to *The Little Earth Book*. However, in doing so, we replace high-carbon forest with extremely low-biomass, low-carbon agricultural land, while also causing even greater carbon loss from the apparently inevitable topsoil erosion.

The carbon lost to the atmosphere via soil erosion and deforestation is emitted as carbon dioxide – reinforcing the greenhouse effect. Food crops that cover a sixth of the planet's surface make up a tiny fraction of one per cent of the overall plant carbon or biomass - a huge loss of biological carbon from the previous forest. We gain short-term agricultural productivity at the price of enormous loss of soil and tree carbon to the atmosphere. However, with the land we already have converted to agricultural use, we can produce enough *plant* food to feed ourselves many times over – it's the ecological losses of producing *meat* that require so much land.

Which is more important, food or carbon storage?

Most sources agree that we add about ten billion tons of carbon a year to the atmosphere, (around 1% of atmospheric levels per year) mainly from the burning of fossil fuels. A smaller amount - probably two to three billion tonnes per year - is released from land-use change.

Year by year, this carbon release builds up significantly, and is the clear major cause of our currently accelerated climate warming (otherwise we would expect to be nearing the end of a warm period and dropping into another glacial cycle). However, this annual release, enough to warm our climate, is *less than one per cent* of the carbon stored in earth's soils and trees.

The obvious way to absorb this extra carbon is via soil buildup and tree planting. This is the opposite of the way things are currently going, and would require a large-scale about-turn on the way we do things, but with not too much consistent effort, the soil and trees – by far the biggest biological carbon stores on earth we can easily manipulate – could absorb all of our emitted carbon.

Early Amazonian civilisations had to contend with extremely poor rainforest soils. They buried charcoal, compost and sewage and this mixture built thick healthy soils that survive and hold large amounts of carbon in heavily rain-washed regions *centuries* later. The principle works as well if not better in other marginal environments. At the same time as locking down carbon, we could be putting our organic waste to better use, solving fertilizer pollution, sewage pollution and flooding issues; We could fertilize our marginal lands, build in soil and biomass, revitalize the earth and soak up some of the moisture that currently causes flooding all at the same time.

There is a down side to all of this, of course. Forest is not very productive of food, at least not in the ways we are used to getting our food. So we'd need to build some of this soil, sewage and compost into agricultural land, and rethink how we feed ourselves.

Norman Myers' book *Perverse Subsidies* highlights an interesting 'fact paradox'. Large scale US agriculture is the most efficient in the world, when measured in terms of cost in dollars per tonne yielded. It is also the *least* efficient on earth, when measured in terms of energy input (in the production and transport of fertilizer, or in the fuel for agricultural machinery, for example) per tonne. This mismatch between economy and ecology could be tolerated while there were four and a half billion people, most of them poor and vegetarian, thirty years ago. Now, however, with our much larger populations demanding more meat, we can't afford to be so energy-intensive and inefficient in our crop production.

Can we be we carnivorous?

Humans have an omnivorous digestive tract, and as we get wealthier we demand more meat. The meat we evolved to digest and assimilate as part of our largely vegetarian diet was game meat - lean, high-protein flesh from wild animals, far removed from the rapidly-fattened, fat- and cholesterol-heavy, hormone- pesticide- and herbicide-laced meat produced by modern agricultural practices. Dr Michael Greger has compellingly highlighted strong links between our modern carnivorous and dairy diet and 14 out of the 15 leading causes of death in the US.

The ecology of ruminants mean that for every tonne of beef, you generally need sixty or more tonnes of low-quality plant food (grazing or the ingredients of feed meal) to feed it. Pork requires somewhat less, chicken about a third as much and small fish less than a quarter the amount of food that beef does. You can grow a third of a tonne of beef in a hectare, a little over a tonne of chicken or, depending on the species, from 200 kilos to 3 tonnes of farmed fish.

With the majority of plant biomass being trees, only a tiny proportion of the global plant biomass (grain and grass) is available to animals as food. Only a fraction of 1 per cent of terrestrial carbon ends up incorporated into animals. The pies shown above reflect artificially high biomasses of agricultural animals and humans. They may look small next to plant and soil biomass, but they are larger than any large animal life earth's history has ever seen.

If we want to continue eating small amounts of meat, we need to somehow combine meat growth with forest growth. Energetically, we need to eat less meat, raised locally (and organically), feed it with local food and eliminate any supplementation that requires transport.

Food for fuel

As well as meat, our cropland is being funneled more and more for 'biofuels' – the horrific practice of ripping up huge tracts of forest, and burning off their carbon, to make way for 'sustainable' fuels. Enormous areas of rainforest in Malaysia and Indonesia have already been stripped of their carbon and biodiversity to make way for palm oil plantations.

Palm oil is by far our most efficiently-produced food oil; it is a vital global food resource, found in the majority of modern processed foods and many other products. However, converting more rainforest to palm oil for growing fuel rather than food is the last thing we need with an atmosphere building with greenhouse gases.

Protein production and carbon absorption from the seas?

Cold-blooded fish converts food to useable protein slightly better than chicken, and more than four times as efficiently than cattle, so fish need a correspondingly smaller area to produce the same amount of protein. Food yields from the sea tend to be natural – we don't (intentionally) fertilize or farm very much of the sea. There is no need to sow, tend to or put any of our energy into the production of wild-caught seafood. If harvested carefully, these food yields can replenish themselves.

This is a big ‘if’. Modern fisheries management is still based around the politically-driven concept of 'maximum sustainable yield', which rests on some decidedly dodgy ecological assumptions. On this shaky foundation overfishing is not only allowed but subsidised. Our demands for wild fish protein have led in a handful of decades to the crashing of the majority of the world’s fish stocks.

The oceans simply do not produce food as robustly as land does. We currently take about 85 million tonnes of seafood from the seas each year, and we're finding less than a decade ago despite increased fishing effort and technology. According to the global network of fisheries scientists estimating Illegal, unregulated and unreported fishing, catches peaked about twenty years ago, despite increased technology and increased fishing effort. The oceans no longer produce as many fish as we take out.

Anything high up on the food web (predatory fish like tuna, sharks and swordfish, and certainly marine mammals like whales or dolphins) cannot replenish itself fast enough to ever be a significant food for the sheer number of humans on earth. As one of seven billion potential fish eaters I cannot ecologically justify eating any fish larger than my hand.

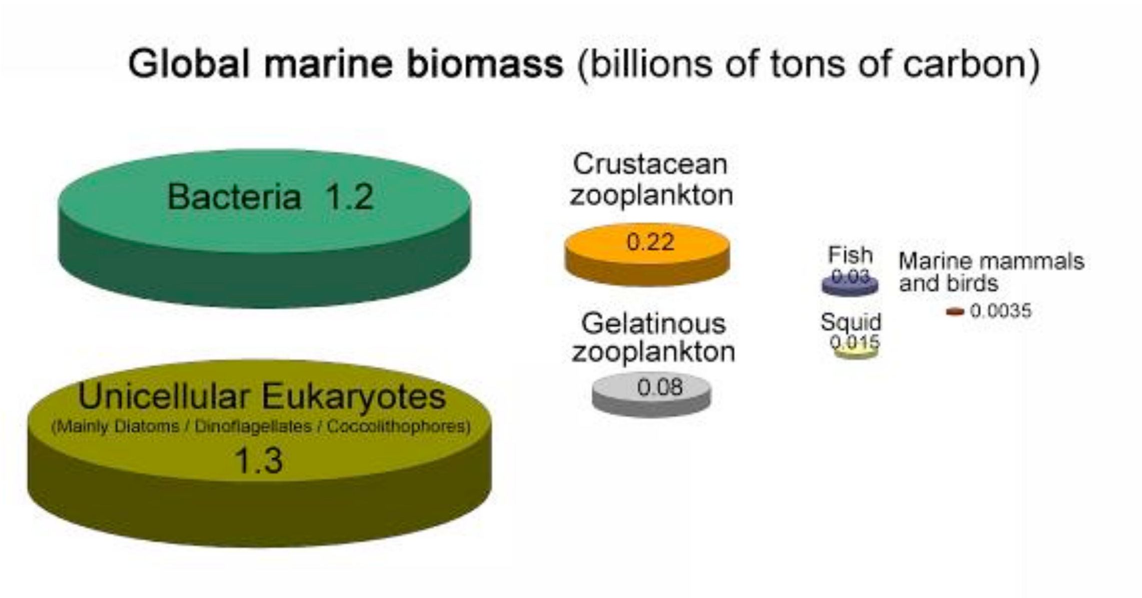
Fishing a wider variety of species, lower down the food web, the oceans can produce enough for us to harvest sustainably. The smaller tropical tunas do an amazing job of foraging vast areas of 'ocean desert' – seas too unproductive to support much else. Squid produce protein with extremely high efficiency, but we struggle to effectively find and harvest all but a few species. With small fishes or krill we only fish where there are dense concentrations, and tend to deplete these and miss the more dispersed majority.

But in the last 50 years, tuna catches worldwide have grown from one to nearly ten million tonnes per year. In the same period, the adult biomass of these tuna stocks has dropped from 30 to ten million tonnes. Even populations of the small warm-water tunas, traditionally the 'rats of the sea', the only fish that could effectively forage the vast tropical ocean deserts - are plummeting. I now have to admit that my friend is right, and I will not eat carnivorous fish. I no longer find that tin of tuna acceptable.

We haven't yet found a way of increasing yields of food from the sea as we have with agriculture on land. Aquaculture, though, has grown rapidly to provide large amounts of food, up to over 50 million tonnes a year in the last decade or so. There has been a huge cost to ecological efficiency (most farmed fish are carnivorous, and are fed baitifsh, which are themselves fished at high environmental cost) as well as local pollution costs.

However, herbivorous farmed fish may offer solutions. Tilapia and *Pangasius* have become widely available recently. They produce protein more ecologically efficiently than even chicken or squid, and depending on what they have been fed can taste pretty good, too.

As mentioned, the seas are less productive than the land. Additionally, the overall mass of living organisms in the water column is hundreds of times smaller than that on land. This relatively tiny amount of life is turned over and replenished on considerably shorter timescales than plants on land, (most of it in days to weeks rather than decades) and this is how the oceans can surprise us. Strangely, from both the perspectives of both food and carbon, the tiny amount of life in the oceans may offer some solutions.



While on land we are weakening the biosphere by deforestation, soil erosion and pollution, the oceans are still quietly soaking and sequestering carbon from the atmosphere. In productive, cold deep water areas such as the waters off the Antarctic and northwest Pacific, the rapid turnover of the plankton is grabbing about a quarter of our carbon emissions, perhaps two and a half billion tonnes a year, and dropping them as faeces, moults or food pellets to become incorporated into the largest long-term carbon store of all, the sediments of the deep ocean.

There have been experiments, some of them rather successful, on fertilizing the seas with iron to encourage this process. Iron is the 'missing nutrient' in most oceans, and adding iron gives a boost to phytoplankton production, which then gives a boost to zooplankton, whose moults and faeces make up the vast proportion of the biological pump that draw down the carbon to the seafloor. Question marks remain, but it seems that from a carbon perspective, the oceans can give us good news.

Where do we go from here?

So where does this all leave us? Am I right or is my friend (or are we both a bit wrong)? Assuming we are going to allow the poorer majority of the world to aim for our lifestyle, then we are approaching (or have already passed) 'food production saturation'. The seas don't really produce enough large animals (certainly not enough tuna, sharks, dolphins or whales) to be a long-term food source for this many people. Plankton, squid and tilapia are potential long-term, high-efficiency seafood sources.

I still argue that beef is the single most ecologically-damaging food that we eat – together with the meat of other pasture-fed, intensely-reared agricultural animals. Organically-raised chicken, milk and eggs are our best bets for land-reared protein. The sheer scale, and the direct and peripheral impacts of our agri-meats are unprecedented in the ecological history of this planet.

Fundamentally, the vast majority of the bulk of our diet needs to be vegan. The land can produce plenty of vegetable matter, but meat as we currently produce it costs far too much carbon lost to the atmosphere by way of soil and tree loss. We'd need to grow our much smaller amounts of meat on woodland, and transport it far shorter distances. There are promising organic polyculture experiments that show signs that growing meat and vegetables at the same time as enriching soil and tree biomass, without bringing in fertilizers or pesticides, is possible.

We can make huge changes by eating only locally-produced food, and by reverting to something like an 90:10 diet (90% vegetarian or vegan meals, 10% meals including organically-produced lean meat, which would incidentally bring enormous health benefits). Otherwise we need to cultivate woodland-friendly (or estuary-friendly, or scrub-friendly), harvestable rather than intensively-raised meat sources. Game animals and birds would be ideal nutritionally and better ecologically, but their current populations would not stand regular harvesting at the scale our species now exists.

Whatever foods we choose, we are going to need to reinforce the marginal areas at the edge of deserts by actively building soil – ideally ploughing all of our organic waste into building dark, moist soil mass. It is time to start building, both soils and seas, because we've reached the point where the degradation of both makes our position untenable. This is not an impossible task – it's surprisingly simple, and immensely satisfying, while at the same time making our biosphere a richer and more beautiful place to live.

So I guess Rinie and myself were both right – if we assume that everyone has the same rights and wants as ourselves we really shouldn't eat either beef or seafood the way we currently harvest either of them.

Whatever way you look at it, though, wherever you draw your lines and however you fudge your figures, the only conclusion that can be reached is this; This planet cannot feed seven billion people if those people want to eat as we in the 'developed' world eat. If we insist on trying, the changes we'd need to make would make our current rates of atmospheric carbon increases seem tiny. The way we currently feed ourselves gives us two choices – either a carnivorous and piscivorous diet or a stable atmosphere. If we want both, we are all going to have to redraw some lines.