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Comment on Searchinger et al. 2018

Comment on Searchinger et al. (2018) "Assessing the efficiency of changes in land use for mitigating climate change", Nature 564: 249

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1. Context

Some days ago, the article from Searchinger et al. 2018 has been published and caused quite some discussion in the media, basically being reported to show that organic agriculture is bad for the climate.

In the following, I present some fastly written compilation of thoughts on this article and this claim from the media that reported on it. Regrettably, this paper is quite difficult to read, and the arguments and how exactly the calculations have been done are often difficult to follow. I hope these thoughts are helpful in the discussion. I start with some more general aspects in the paper in sections 2 to 4, then addressing the indicator they suggest in section 5, specifically doing some short comparison of this paper to Muller et al. (2017; https://www.nature.com/articles/s41467-017-01410-w) in section 6, and providing some short suggestions on how to answer potential media questions on this paper in section 7.

Please send me any comments, criticism and suggestions for improvements you may have.

2. What the paper is about

The authors state in the introduction: "*We define a more 'carbon efficient' use of land as one that increases the capacity of global land to store carbon and reduce greenhouse gas emissions (GHGs) overall, while meeting the same global food demand.*" Thus, they are interested in how to use each hectare of land in such a way as to maximise climate change mitigation while meeting global food demand. Generally, the thought behind this is as follows: if we produce 4 tons of wheat on one hectare organically and 6 tons conventionally, then we need 1.5 hectares under organic production to produce the same output as 1 hectare under conventional production. The carbon efficiency view then addresses whether the mitigation potential is higher when cropping 1.5 ha with organic wheat than cropping 1 ha wheat conventionally plus growing forest (for example) on 0.5 ha. To decide this, the authors suggest to basically do a full greenhouse balance (including soil carbon, fertilizer production, N_2O emissions from fertilization, etc.) of conventional and organic wheat production, as well as of alternative uses of the area, such as forest. A central concept therein is the carbon storage opportunity costs, which the authors introduce as follows as "l*and's opportunity to store carbon if it is not used for agriculture, which we call its carbon storage opportunity cost.*" Thus, the additional 0.5 ha cropped with organic wheat comes with carbon opportunity costs of e.g. growing a forest on this 0.5 ha.

Thus, the authors suggest to not only compare GHG emissions and soil carbon sequestration or losses of different production systems on a per kg basis, but to add the emissions and sequestration changes that come from producing part of this kg elsewhere in case one production system needs more land and the two production systems thus do not produce the same amount on one given hectare. This is a useful amendment of classical LCA approaches. It is an approach that is in-between a product quantity related LCA approach and a full food-systems mass flow model, that includes such land use effects due to the global assessment of production patterns (e.g. Muller et al. 2017, https://www.nature.com/articles/s41467-017-01410-w; I address the differences between these two papers in section 6 below).

It has to be emphasized that the authors do not mention organic production prominently in the paper – it is used in one example only – but they partly referred to the example of organic vs. conventional in the media for illustration and the whole setup is such that any production system that needs more land is a clear example for a production that causes more GHG emissions. An example for the prominent use of the organic topic in the media is a contribution from the co-author Stefan Wirsenius from Chalmers, where the organic topic is even taken as the header for the blog and the main illustration is this tiny example with wheat and peas from the paper: https://www.chalmers.se/sv/institutioner/see/nyheter/Sidor/Ekologisk-mat-samre-for-klimatet.aspx.

Given the current context of discussions on agriculture, food systems and climate change and given how the media work, it is then very understandable that the media try to frame this as a story on organic agriculture. I do however not understand why some of the authors act similarly (cf. the blog linked above).

3. Lack of a systemic view – focus on efficiency, disregard of total system size changes ("Sufficiency")

The authors then state "*Yet because land supply is fixed, only increasing its efficiency can allow the world to meet both climate and food goals.*" This is a flaw in the setup of their analysis, as they basically pose that demand cannot be changed. However, we know from other studies that it is central to look at the whole food system and not only at production when addressing sustainable food systems, i.e. that demand and changing demand is a central aspect of sustainable food systems (i.e. sufficiency is central, see e.g. Muller et al. 2017, https://www.nature.com/articles/s41467-017-01410-w). Thus, depending on how demand is measured, the statement above is not true: global food demand measured in calories and protein can be met without increasing total GHG emissions even with production systems that are not optimised for carbon efficiency (e.g. grass fed ruminants), in case we shift to lower animal source food levels in our diets and to reduced food wastage. If, however, demand is measured to be equivalent to a business as usual scenario, i.e. with the corresponding high level of animal source food and wastage, this is indeed not possible.

4. Efficiency in one single indicator vs. multidimensional sustainability assessment

The authors add a strange example on SUVs for illustration: "*To appreciate the distinction [i.e. to show that the economic approaches do not capture the carbon opportunity costs], we imagine a possible economic analysis of a strange climate policy banning all cars except petrol-guzzling, expensive, luxury SUVs (sport utility vehicles). The efficiency of driving would decline, increasing emissions per kilometre. However, if the cost of driving rose high enough, an economic model might estimate overall GHG savings by forcing many people to stay at home and others to switch to public transit. Even if these outcomes were real, these switches would not make SUVs more efficient than economy cars.*" Here, they miss the point that it is not GHG emissions per km that count for the climate but total aggregated GHG emissions. In this example, total GHG emissions drop, while the remaining technology is not efficient. But in case a climate policy on mobility would only be accepted by the population if only high taxed SUVs survive (strange assumption, but the whole example is strange), then this may be a good option – and it would surely deliver much benefits on urban area use for parking lots, streets and on congestion. This is similar to grass-fed ruminants, for example: if we only had ruminants fed on grass, animal numbers would drop that much that total GHG emissions would be reduced – albeit emissions per kg protein would increase. But this would have other benefits, such as reduced cropland use, etc. Thus, efficiency is not the only measure to base decisions on and regarding GHG emissions it is the total emissions that count, not the relative emissions. Finally, GHG emissions are only one among many sustainability aspects – therefore, carbon-inefficient solutions may be more sustainable than carbon-efficient solutions when looking at more dimensions.

However, the authors explicitly state that they are interested in climate change mitigation only and not in any other sustainability aspect (from the abstract: "*Here we propose a carbon benefits index that measures how changes in the output types, output quantities and production processes of a hectare of land contribute to the global capacity to store carbon and to reduce total greenhouse gas emissions. This index does not evaluate biodiversity or other ecosystem values, which must be analysed separately.*"). This is legitimate from a scientific point of view, but dangerous, when discussing results in a broader context and when reaching out with the results to a broader public and the media, as it leads to conclusions that solve one problem only and do not account for trade-offs with other aspects of similar importance.

In this context, the authors then state: "*The actual efficiency of driving matters because governments can reduce GHGs more generally by using fuel taxes and transit subsidies to encourage less travel and higher use of mass transit while also requiring vehicles that are more fuel-efficient.*" Thus, they correctly state that there are more efficient ways to reduce GHG emissions from mobility than switching to few inefficient SUVs only. However, if the whole car fleet changes to electric cars, then the GHG emissions are greatly reduced – which is a huge success, but none of the space and congestion problems would be solved – thus, on a more encompassing sustainability metric, it may not be that successful.

The authors then continue: "*Similarly, if governments wished to use higher prices to reduce food consumption and spur yield gains, they could reduce GHGs more using taxes and subsidies while encouraging only efficient land use changes (LUCs). To implement such policies, however, governments need to know which LUCs are more efficient in themselves.*" This is a legitimate approach supported by economic reasoning if the goal is GHG mitigation and nothing else. And this is the reason for the authors to introduce their new measure, as such an approach necessitates to have an index that captures all "carbon costs" of using a ha of land, to set correct incentives for carbon-efficient land use. Hence their index: "*Our carbon benefits index provides such a measure, expressing benefits as kilograms of CO2 equivalent (CO2e) emissions per hectare per year.*".

5. The carbon benefits index

The authors then start describing their index (top left on page 250), which is not an easy read, I think. I try to reformulate this to make it more accessible (hopefully with some success…). The index has the following components:

i) On-site carbon storage and bioenergy production: "*The index first incorporates the outputs of a hectare that are directly quantifiable in carbon terms. These include any changes in carbon storage on site, as well as net reductions in GHGs from displacing fossil fuels with bioenergy.*" Thus for any ha used in a certain way, it is assessed how much carbon is stored or lost with respect to the baseline and, in case the new land use generates bioenergy, it is assessed how much fossil fuel emissions can be reduced by using this bioenergy.

ii) Carbon losses from food production: if the new land use produces less (or more) food than the baseline, this amount of food is assumed to be produced elsewhere (or production elsewhere is reduced correspondingly); for this, the authors then assume that this amount of food produced elsewhere comes with the global average of carbon costs for this food. These carbon costs of food produced elsewhere in replacement of foregone (or additional) food production on the ha of interest have to be accounted for. They are calculated as follows: either as the sum of all carbon losses that arise from the global production of this food (i.e. soil carbon losses and losses from deforestation, for example, incl. feed carbon losses for milk or meat production, for example), divided by the global quantity produced of this food (the "carbon loss method"); or by assessing how much land is needed to replace this food assuming global average yields, and then growing average forest on this land. The carbon costs are then the foregone sequestration from not growing this forest, as the area had to be used to produce the replacement food. This is the "carbon gain method".

These costs are called the "carbon opportunity costs" COC. In addition, they account for some time-dynamics by "discounting" (which I did not fully get how they did it), which sort of accounts for additional costs of doing mitigation actions later rather than earlier (if I got this right).

iii) These carbon losses do not yet account for production emissions (PEM), which are reported separately. The production of food elsewhere comes with global average production emissions (from fertilizer application and production, methane from enteric fermentation, etc., I assume). So this is added to the carbon opportunity costs. If food produced on a certain hectare would have higher production emissions than the global average, these opportunity costs are lower and relocating production would result in gains regarding this part of the opportunity costs, and the other way round.

Thus, in summary, the carbon benefits index for a certain land use or cropping system change on one specific hectare in a certain location X is calculated as follows: It equals the sum of a) gains or losses of carbon elsewhere (the carbon opportunity costs COC) due to displacement of production from X to elsewhere or from elsewhere to X; b) the change in production emissions of producing or not a certain food in X, compared to the global average emissions from this food production; c) the change in carbon (soil and biomass) in location X, due to the production change; d) in case the change in X results in bioenergy production in X: emission reductions due to replacing fossil fuels with bioenergy.

In general, this is a legitimate approach to account for the GHG effects of a production change on a ha in X, in the context of a fixed baseline global crop and forest production and assuming fixed demand. Before proceeding to some examples, the authors state "*The index separates the efficiency of consumption from the efficiency of each hectare's production into different analyses. The higher a product's COC, the costlier its consumption, but also the more beneficial its production. For example, consuming a kilogram of beef costs more carbon than consuming a kilogram of soybeans, but producing a kilogram of beef generates more benefits because it frees up more carbon storage capacity elsewhere, assuming fixed demand.*". I have to admit, that I do not get this. Because the index does not only account for COC elsewhere, but also for the carbon changes and emissions in the location looked at, this positive/negative net effect depends on the situation at hand. If on a hectare soy is replaced by grassland and beef, then the index is built from COC and emissions from global average soy production that arise elsewhere, the reduction of global average grassfed-beef production elsewhere, the emissions of this production on the hectare of interest, and subtracting the emissions from soy production on this hectare of interest (as this does not take place anymore). So switching to beef in this example is beneficial only, if the production on the hectare of interest is more efficient than the global average.

6. Short comparison to Muller et al. 2017

In Muller et al. (2017, https://www.nature.com/articles/s41467-017-01410-w), we also calculated the GHG emissions from switching to organic agriculture and found that a world with 100% organic agriculture would have similar GHG emissions as the conventional baseline system (which is the world in 2050 as projected by the FAO in 2012). Muller et al. (2017) use a global mass flow model and thus account for increased land use of organic production and thus, in principle, for these carbon opportunity costs. The two papers are not easily comparable, as Muller et al. (2017) calculate a switch to 100% organic globally, while Searchinger et al. (2018) look at single product footprints and never scales this up to a larger scale. Nevertheless, in tendency and as it is communicated in the media, one could think that these papers contradict each other. The differences likely arise along the following lines:

First, the increased land use in Muller et al. (2017) also comes with a certain GHG - footprint from deforestation and from drained organic soils, as we linked land use and deforestation/organic soil utilization rates in each country and assigned a corresponding deforestation/ organic soil utilization share to each hectare land used in a country. Thus, we have some carbon opportunity costs of increasing land use, but this is lower than in Searchinger et al. (2018), as we did not assume that each additional ha would result in a full hectare being deforested.

Second, we did not account for soil carbon, as we aimed at being very conservative in our estimates and the meta-analysis of Gattinger et al. 2012 provided only insignificantly increased soil carbon levels in closed systems – which we would have to take as a basis, as in a world with 100% organic, there is no additional biomass from outside that could be put on the fields. In addition, only closed systems are sustainable, as otherwise, there is a danger of soil carbon mining outside the system boundaries. Hence our omission of soil carbon. Searchinger et al. (2018) on the other hand did not differentiate soil carbon between organic and conventional production and did not address potentially higher soil degradation in conventional systems, that potentially could reduce the relative carbon benefit from conventional systems.

Third, we have a nitrogen deficit in the 100% organic scenario in Muller et al. (2017), resulting in an underestimation of nitrous oxide emissions that come from the organic production system. On the other hand, we do not cover off-season legume leys, etc.

(due to lack of data), but this is also not specifically included in Searchinger et al. (2018), I think.

Forth, we do a global scenario, so we use more land and crop it organically to produce the same amount as the conventional world. In Searchinger et al. (2018), the approach is different: they would crop one hectare organically and then crop the additional area needed to have the same production conventionally with correspondingly higher emissions per ha (but somewhat lower area use on this additional area as it is conventional – thus the net effect of this is not clear).

Fifth, Searchinger et al. (2018) only look at two crops in Sweden, with relatively high yield gaps for their organic comparison. We look at the whole global food production, with on average lower yield differences and thus lower land use and related carbon costs.

7. Some suggestions for answering media inquiries on Searchinger et al. 2018

- Searchinger et al. (2018) do not systematically compare organic and conventional production at a global or any larger scale and covering a significant number of crops and livestock operations. They only use organic production to illustrate their new index with two comparisons from Sweden (wheat and peas) and the comparison organic/conventional is not in any way central in the paper. Biofuel, for example, plays a much more prominent role, also with controversial results. Organic agriculture is however made very prominent in the media communication of the researchers (e.g. Stefan Wirsenius) – but this is not legitimate given what they did in the paper.
- They partly base their negative judgement of increased land use per kg output on the assumption that demand cannot change. This neglects a food systems perspective that is central for any larger-scale analysis of sustainable agriculture and related statements. Accounting for changes in the size of the food system can provide the room for having "inefficient" production while in total still performing well on all sustainability indicators.
- Such a systemic and encompassing approach is presented in Muller et al. (2017), which provides a more adequate assessment of what a large-scale conversion to organic production may mean, also regarding GHG emissions. It shows that the emissions would in total not increase (on this discrepancy to Searchinger 2018: see the previous section). With changes in demand, emissions would decrease, even in a world of 100% organic production.
- Searchinger et al. (2018) are explicitly only interested in GHG emissions and carbon sequestration. This is legitimate and helps to increase clarity when assessing these topics – but it bears the danger of neglecting other central sustainability aspects. They make this explicit in the paper, but when

communicating in the media, only the climate change aspect and the bad performance of organic regarding this is mentioned. When talking about sustainable agriculture and food systems, it is central to complement GHG performance with other sustainability indicators and to transparently communicate potential trade-offs. In research, the restricted analysis is ok, as it helps to clarify these issues, but when communicating with the public, this needs to be set into context to avoid such biased debates.