Food Ethics

Problematic quantifications: a critical appraisal of scenario making for a global 'sustainable' food production
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Problematic quantifications: a critical appraisal of scenario making for a global ‘sustainable’ food production

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Over the course of human history food security has represented a primary challenge for civilizations and societies. In the light of the projected trends of population expansion in the forthcoming decades, its primary importance in the global agenda has never decreased.

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Keywords: Food security, sustainability, sensitivity auditing, quantitative storytelling, food distribution, ecosystem alteration

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Introduction

A recent paper entitled ‘Pathways Leading to a More Sustainable and Healthy Global Food System’ (Badur et al. 2016) presents an analysis of a possible scenario for the interplay between agriculture and world nutritional needs.

The analysis takes the form of a hypothetical executive summary from an imagined report from the Food and Agriculture Organization (FAO). The subject of the report is the state of the world’s food systems, written from the perspective of the 2050s.

The study assumes that the world population will have attained 10 billion people, and that agriculture will require “438 million hectares less land than it did in 2015”. According to the report this improvement owes much to technological developments, including the application of big data analytics to farming systems in the 2010s and 2020s. Even larger, according to the authors, is the effect of a change of consumption pattern.

The authors imagine a marked shift from the 2015 situation (we recall that the piece is written from the 2050 viewpoint), characterized as systematically overproducing cereals and starches, oils and fats, and sugars, coupled with a lack of 2/3 of amounts of the fruits and vegetables needed for everyone to enjoy a nutritious diet. The authors also refer to a previous (e.g. present day) UN estimate that concludes that there were possibly no lack calories: 3,000 dietary calories per person per day were (are hence today) available on the planet. The consequences of overproduction of cereals, oils and sugars were type II diabetes, obesity, and an overuse of agricultural land.
The authors imagine hence that in the intervening period between present day and 2050 a set of virtuous policies have managed to improve the situation. The policy package includes:

1. **Consumer Education**, in the form e.g. of better food literacy and cooking skills
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3. **Policies Geared at Capturing the Hidden Environmental Costs Associated with Farming.** This foresees a comprehensive market for carbon in order to limit greenhouse-gas emissions from agriculture as well as restrictions on the use of antibiotic use to limit livestock production.
4. **A Reduction in the American Corn Subsidy.** This policy also aims to raise the price for livestock feed, and for products which contribute to the processed food industry such as high-fructose corn syrup and corn-starch.
5. **Enhanced Storage and Processing Facilities in the Developing World.** Unlike the previous measures, this specifically targets the ‘Global South’.

In this contribution we intend to present a critique of this work. The theoretical framework underpinning our appraisal borrows from the tradition of system ecology (Odum 1968), as well as from the more recent methods of sensitivity auditing (Saltelli and Funtowicz 2014) and quantitative storytelling (Saltelli and Giampietro 2016).

**Discussion**

The Authors’ bottom line is that “agriculture requires 438 million hectares less land than it did in 2010”.

This 438 Mha figure was arrived at by assuming that:

1. Agriculture shifts away from over production of cereals, oils, and sugars, but increases fruit and vegetables;
2. Agricultural yields increase ~1%/y between now and 2050.
3. Protein consumption shifts from 86% animals and 14% plants to 50% animal and 50% plant.

While the paper notes that the authors can be contacted for references pertaining to the calculations we feel that we have enough ingredients on the table to sketch a critique of the analysis.

a) How can the hectares extension be given with three significant digits (438 millions)? The many assumptions feeding into the analysis would probably suggest a one digit precision. The most comprehensive database currently available, the FAOstat metadata (FAO, 2017), see [http://fenixservices.fao.org/faostat/static/documents/RL/RL_e.pdf](http://fenixservices.fao.org/faostat/static/documents/RL/RL_e.pdf) warns about the accuracy of the available data due to the lack of consistency and accounting method across countries. A quantification of the error and of the uncertainty in the output would have been appropriate.

b) What percentage decrease of the available land does this number corresponds to: 5? 10%? A quick look at the sources tells us that total agricultural land in the world amount to some 4.9 billion hectares (FAO, 2014 datum). This would imply a 9% reduction in land use but this should have been made clear in the article out front.

c) Assuming it refers to an average figure, a one per cent increase in yield over the 35 years separating the authors from the 2050 gives a total increase in yield of $e^{0.35} = 1.4$. Applying this increased yield to the reduced area computed in (b) gives an overall increase in output of about 1.3.
d) Population has been assumed to increase from 7.4 billion (in the year 2015) to 10, corresponding to a factor of 1.3. Thus, the increase in output would merely balance the increase in population. This would assure the same average food availability at the global level as per today.

e) Assumption (c) was derived assuming a growth rate of about 2% in the period between now and 2050, decreased to 1% as per the effect of climate change. One should perhaps also consider the principle of diminishing return, whereby the more efficiency needs to be increased, the more the increment becomes arduous to achieve (Byerlee 1992; Tilman et al. 2002; Struik et al. 2014).

f) The assumption of a less caloric diet is questionable. The authors appear to neglect the expected shift in the population composition by the year 2050. The population projected for the year 2050 will present a higher share of adults given the forecast reduction in natality (Tobergte and Curtis 2013). As adults have higher caloric dietary requirements than children, an overall decrease in cereal production is questionable.

g) The present trend sees a growing meat consumption in a regime of increasing income in developing countries (Smil 2013). Thus, the worldwide desirability (see below) of a change of course is dubious (Gomiero 2016).

h) The effects on the ecosystem of the assumed yield increases are neglected. It is hard to imagine that such agricultural intensification would lead to a decreasing environmental pressure, rather a significantly higher ecosystem alteration is foreseeable (Mario Giampietro et al. 1992).

i) The role of legislation and education is emphasized in the article as a valid strategy to achieve the change in the patterns of consumption advocated in this piece. We doubt that a so-called ‘food literacy’ plan would work on a planetary scale. Exactly as for the case for smoking – mentioning in the piece as an example – a decrease in some developed countries corresponds to an increase in developing ones. Also to be considered are the profound differences in cultural values, and the fact a significant share of the world population in developing countries live under fragile regulatory systems. Even at the national scale, the elaboration of an effective policy is hampered by the disparities in income, ethnicity and age, i.e. the diversity of the people a society is made of. The effectiveness of the campaigns promoting fruit-and-vegetable-based healthy diets has shown to be limited in spite of the consistent resources allocated (Rekhy and McConchie 2014). Finally, the role of possible agricultural-sector lobbies should have been better discussed at the planetary level.

Finally two additional technical points are made:

j) The definition and metering of ‘fruit and vegetable intake’ is also affected by cultural and ethnic values that make the comparison semantically ambiguous and less robust across studies from different areas and on different societal groups. Different ethnic groups tend to address in different ways the survey questions related to dietary intakes as reported by (Roark and Niederhauser 2013). Is potato intake also in the form of French fries to be considered as vegetable intake? How about onion and tomato slices as well as lettuce when used in small portion as condiments? Perhaps a clear definition of fruit/vegetable serving would be required as this affects the current accounting practices, as well as the proposed policy goals.

k) The paper builds on the postulate that the system can smoothly readjust to its change and seems to neglect possible inelasticity. For instance, the investment required (Demsetz 1969) for a massive production shift from cereals, plant oils and so forth towards vegetables seems to have been neglected. Furthermore, no lowering factor for yields is adopted to take into account the readjustment time.
In summary this study is poorly framed as the problem of today – and likely the challenge of tomorrow as well – is that food is unequally distributed (Falconí et al. 2017). When assessed per kilogram of body mass, caloric intake is not lower in developing countries in comparison with developed countries due to the higher share of children in the former (M Giampietro et al. 2011). A higher share of vegetables and fruit in the diet can be certainly desirable worldwide, but we doubt that this can be implemented at the cost of reducing cereal cultivation. The optimistic imprint of the article – which identifies a problem and proceeds to offer its solution – has been achieved at the cost of selecting a dubious frame, where food production is unbalanced, too much land is being used and agricultural production can be made more intensive. The article does not offer an estimate of the different balance of fertilizers and pesticides needed in the new scenario, an aspect that would be essential for a thorough assessment of the feasibility and viability (see below) of the proposed transition. An assessment of water use should have been produced as well. As water is primarily withdrawn and used in agriculture (Mekonnen and Hoekstra 2016; Dalin et al. 2017) its local scarcity could pose significant challenges for an effective coexistence of agricultural activities with other economic activities.

Contrasted with the global injustice of nutritional inequality we find the policy mix and the inference of the piece appear possibly unethical, determined as it is by a developed world perspective. This is evidently the substitution of a political problem with a technical one, whereby the world’s nutritional unbalances are not the results of a power asymmetry, but of a mere “mismatch between what the world needed for everyone to enjoy a nutritious diet and what the world was actually producing”. Additionally, the use of crisp numbers – even in the avowed context an imaginary report - convey a spurious impression of accuracy, which could be termed as rhetorical.

Conclusions

Our reading of the analysis presented by Badur et al. (2016) has highlighted technical and normative issues.

A major technical issue is that a higher yield from a given amount of land can only be obtained by increasing the external inputs in the agricultural process along with the ecosystem disturbance. This is due to the fact that the biomass grown and taken away is not available for the ecosystem reproduction and this can only be accomplished at the price of linearizing the nutrient flows – i.e. by neglecting the need for a fund – the agricultural land – to regenerate itself in the process (M Giampietro and Lomas 2014).

Sensitivity auditing (Saltelli and Funtowicz 2014) and quantitative storytelling (Saltelli and Giampietro 2016) suggest looking at modelling at quantification with an eye to the explicit and implicit frames and assumptions, and to submit those to a reality check based on available data and theory, with a parsimonious use of models and numbers. Thus, we employed a form of sensitivity auditing when checking the assumptions of the Badur et al. (2016) study, while the concept of desirability – whether a given policy option can garner support from the intended recipients, comes from quantitative storytelling. The same holds for feasibility – intended as a compatibility with biophysical constraints, and viability, intended as compatibility with societal internal constraints.

More in general we find that the style of analysis of Badur et al., 2016 implies the replacement of a political and ethical question with a technical one.
Already in 1971 philosopher Jerome R. Ravetz (Ravetz 1996) noted that one of the main difficulties which plagued science as applied to the solution of practical problems is a natural slippage into technical ones (p. 342), oblivious of the associated social dimensions and power relationships.

On the opposite side of this debate it is not rare to see science’s advocates attribute the lack of progress to the lay public’s obscurantism and lack of understanding of science (Saltelli and Funtowicz 2017). This latter stance is commonly known as deficit model (Wynne 1993), which we consider as unhelpful as a tool to explain the problematic relations between science and society (Saltelli and Funtowicz, 2017).

Ravetz further notes (p. 398) “The function of such [technical] explanations is to minimize the threat displayed by the problem-situation; this is done either by explaining it away altogether, or, if this is impossible, to give assurance of the possibility of its comfortable resolution”.

Ravetz’s insight is particularly appropriate in light of the ongoing discussion about sustainability of food systems - a central topic of the 2030 Agenda, which will guide decision and policy making in the years to come. Sustainability will need a hard look at power relationships, beyond the comfort of technical solutions.

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Gomiero, Tiziano. 2016. Agriculture and degrowth: State of the art and assessment of organic and


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ABSTRACT

Over the course of human history food security has represented a primary challenge for civilizations and societies. In the light of the projected trends of population expansion in the forthcoming decades, its primary importance in the global agenda has never decreased. However, the issue can be misrepresented by the adoption of doubtful assumptions coupled with misleading quantifications. This is the case with a contribution recently published in the literature (Badur et al. 2016).

Our contribution to this debate comes in the form of a critique of a paper recently published in the literature, Badur et al. (2016). In their work, the authors suggest that continuous improvements in agricultural techniques and dietary re-adaptation and evolution will lead in the near future (2050) to a reduced use of land to meet man-kind nutritional needs, even when factoring in a projected human population of 10 billion people.

We show that the quantification rests on dubious hypotheses, at odds with present understanding from the field of system ecology, and neglects the core issue that resides in fundamental asymmetries in the food distribution between rich and poor countries. Thus, a political/ethical problem is reframed as a technical one, by mobilizing crisp numbers and analytic prowess to convey an impression of prediction and control, while veiling. We warn that this might veil important underlying ethical issues.

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While (a) to (i) represent our main criticism of the analysis of (Badur et al. 2016) two additional points could be made:

Finally two additional technical points are made:
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Contrasted with the global injustice of nutritional inequality we find that the framing of the policy mix and the policy inference of the piece are possibly unethical, determined as they are by a developed world perspective.

This is evidently the substitution of a political and ethical problem with a technical one, whereby the world’s nutritional unbalances are not the results of a power asymmetry, but of a mere “mismatch between what the world needed for everyone to enjoy a nutritious diet and what the world was actually producing”. Additionally, the use of crisp numbers – even in the avowed context an imaginary report - convey a spurious impression of accuracy which could be termed as rhetorical.

Conclusions

The style of critique presented in the present work borrows from the tradition of system ecology (Odum 1968), as well as from the more recent methods of sensitivity auditing (Saltelli and Funtowicz 2014) and quantitative storytelling (Saltelli and Giampietro 2016) by Badur et al., 2016) has highlighted technical and normative issues.
A major technical issue is that a higher yield from a given amount of land can only be obtained by increasing the external inputs in the agricultural process along with the ecosystem disturbance. This is due to the fact that the biomass grown and taken away is not available for the ecosystem reproduction and this can only be accomplished at the price of linearizing the nutrient flows – i.e. by neglecting the need for a fund – the agricultural land – to regenerate itself in the process (M Giampietro and Lomas 2014).

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We would also like to note, More in relation to general we find that the style of analysis of Badur et al., 2016 implies the replacement of practical problems (which we called political and ethical for ease of understanding) question with a technical ones, theone.

Already in 1971 work of philosopher Jerome R. Ravetz (Ravetz 1996). He noted that one of the main difficulties which plagued science as applied to the solution of practical problems is a natural slippage into technical ones (p. 342), oblivious of the associated social dimensions norms and power relationships. The potential scepticism or hostility

On the opposite side of the affected social actors towards a proposed technical solution, this debate it is often labelled by not rare to see science’s advocates attribute the experts as lack of progress to the lay public’s obscurantism and lack of understanding (Saltelli 2017) of science (Saltelli and Funtowicz 2017). This latter stance is commonly known as deficit model (Wynne 1993), whereby progress would be achieved if which we consider as unhelpful as a tool to explain the lay public would understand better the technical facts, problematic relations between science and society (Saltelli and Funtowicz, 2017).

Ravetz further notes (p. 398) “The function of such technical explanations is to minimize the threat displayed by the problem-situation; this is done either by explaining it away altogether, or, if this is impossible, to give assurance of the possibility of its comfortable resolution”.

Ravetz’s insight is particularly appropriate in light of the ongoing discussion about sustainability of food systems - a central topic of the 2030 Agenda, which will guide decision and policy making in the years to come. Sustainability will need a hard look at power relationships, beyond the comfort of technical solutions.

References


Smil, V. 2013. *Should We Eat Meat? Evolution and Consequences of Modern Carnivory.* EBL Ebooks


### Reviewer #1

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<th>Reviewer comments</th>
<th>Reply to the comment</th>
<th>Change in the manuscript</th>
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<tr>
<td>The Badur et al. policy package includes a lot more than just improved technology - most of the trends seem quite plausible. These authors have set up a future scenario using a set of reasonably plausible assumptions. It is perfectly legitimate to question the set of assumptions as this critique does. But it would be helpful to encourage them to be more rigorous, and, what seems not to have been done in the original paper, to explore the consequences of alternative assumptions on the results. But there is an unholy scent of arrogance in the critique, all of which is pejorative and none appreciative or constructive. Why have the detailed calculation sources available from authors not been consulted? This seems unreasonably cavalier. Why is the scenario exploration denigrated as &quot;story telling&quot; and accused of &quot;obscurantism&quot; the lay public wont understand? Is the implication is that these authors think this Ravetz effect was deliberate or a part of some conspiracy. If this is not the case, then it should be made clear.</td>
<td>We thank the reviewer for sharing his/her point of view. We have tried to make the text clearer, also to clarify some misunderstanding. Quantitative story telling is used in the positive sense. It is one of the methodological approaches used in our analysis to perform a robustness and validity check of the scenario proposed by Badur (2016) et al. The term does not refer to their scenario making – the opposite is the case. Analogously, the reference to obscurantism is not related to the work of Badur et al. It refers to the accuse often put forth by the upholders of the so-called deficit model (Wynne, 1993) which we oppose. We believe that open data means making the data available, not making the data available under request (Morey et al., 2016). The final quote of Ravetz is not a hint to a conspiracy, but to a style of analysis which we disapprove of. This is the main point of our critique.</td>
<td>We agree with this point. The suggestion has been incorporated into the manuscript. [A quantification of the error and of the uncertainty in the output would have been appropriate.]</td>
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<td>A - Too many significant digits - agree with this criticism, but a simple solution is to put some uncertainty limits on the figure NOT round the estimate up or down.</td>
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<td><strong>C</strong> - A quick check on increase in agricultural production on Wikipedia show this assumption at least is borne out by the track record, so why is the deemed unreasonable? It needs a detailed rebuttal of the mainstream literature upon which this is based.</td>
<td>Point c was introduced with the aim to inspect the underpinning assumptions of the proposed assessment. The point <em>per se</em> is not intended to disqualify Badur et al. quantification. The critique of the proposed figure is rather elaborated at point e). We have deleted the sentence where this aspect was unclear.</td>
<td>While (a) to (i) represent our main criticism of the analysis of (Badur et al., 2016) two additional points could be made:</td>
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<td><strong>D</strong> agree, but the mix of food types is quite different.</td>
<td>Certainly, a reflection on the caloric intake and its implications has been presented at point f.</td>
<td>No change in the manuscript.</td>
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<td><strong>E</strong> casuistry</td>
<td>The point has been tackled by incorporating references from the mainstream literature as recommended by the referee at point c)</td>
<td>[One should perhaps also consider the principle of diminishing return, whereby the more efficiency needs to be increased, the more the increment becomes arduous to achieve (Byerlee, 1992; Struik et al., 2014; Tilman et al., 2002).]</td>
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<td><strong>F</strong> - Quibble. Hmm - but more older people who eat less …</td>
<td>Indeed, the population of elderly is foreseen to increase, but still most of the increase will come from other cohorts having higher caloric intakes; from Tobergte and Curtis (2013): [i]n 2015, there were 901 million people aged 60 or over […] By 2050, in all major areas of the world except Africa, it is expected that nearly a quarter or more of the population will be aged 60 or over. The number of older persons in the world is projected to reach […]2.1 billion by 205[0]. Furthermore, the progressive procrastination of the retirement age will force people to work for longer time and therefore to adopt a higher caloric intake profile (European Food Safety Authority, 2013).</td>
<td>No change in the manuscript.</td>
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<td><strong>Fair point, but it developed world it can be argued plausible given health policy trends?</strong></td>
<td>It is certainly plausible a reduction in meat consumption for the developed world. For some countries this has already been</td>
<td>No change in the manuscript.</td>
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However, the decreasing trend in developed countries would be certainly outpaced by the one in developing countries, that is also where the population is also growing at the fastest pace (see the previous point).

H - Yes - but can be countered with present trend of improving ways of minimizing and mitigating ecosystem impacts of GM and other crops.

We believe that GMO diffusion presents high stakes hard to meter in the light of the fact these are not fully known (Taleb et al., 2014). Therefore, we feel whether GMO would help out to mitigate/minimize the ecosystem impacts or rather would exacerbate them cannot be said. That would also depend on the time and spatial scale at which the analysis is performed and we feel this assertion cannot be supported in the spatiotemporal realm of the paper and this critics (i.e. globally, to the year 2050).

I - Fair point. But is it fair to adopt pessimism that all future health policy campaigns will always fail?

We believe not all the campaigns are bound to fail. However, their effects are generally overstated on the optimistic side. Furthermore, the diversity of cultural values, identities and so forth on a planetary scale makes it hard to believe it is possible to tailor such a policy that would be effective for the entire planet no matter what. Let alone that several people in underdeveloped are completely out of the legislators actions. Even taking into account the national dimension only, the elaboration of an effective policy is all but simple given the disparities in income, the different ethnicity groups and ages of the recipients, i.e. the people a society is made of. The point has been further developed in order to better accommodate these reflections.

The role of legislation and education is emphasized in the article as a valid strategy to achieve the change in the patterns of consumption advocated in this piece. We doubt that a so-called ‘food literacy’ plan would work on a planetary scale. Exactly as for the case for smoking – mentioning in the piece as an example – a decrease in some developed countries corresponds to an increase in developing ones. Also to be considered are the profound differences in cultural values, and the fact a significant share of the world population in developing countries live under fragile regulatory systems. Even at the national scale, the elaboration of an effective policy is hampered by the disparities in income, ethnicity and age, i.e. the diversity of the people a society is made of. As a matter of fact, the effectiveness of
the campaigns promoting fruit- and vegetable-based healthy diets has shown to be limited in spite of the consistent resources allocated (Rekhy and McConchie, 2014).

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<th>J</th>
<th>Fair point. But status of a quibble in the face of the scope of the analysis</th>
<th>Well, in quantitative terms the aspect might not very consistent, however the terms are affected by semantic ambiguity that would need to be clarified in the light of the aim to produce an accurate quantitative assessment as the one attempted by Badur et al. The relevance of the point has been better stressed out.</th>
<th>Perhaps a clear definition of fruit/vegetable serving would be required as this affects the current account practices as well as the proposed policy goals.</th>
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<td>K</td>
<td>Unfair - &quot;massive shift&quot; is not what these authors assume - lots of time of gradual changes.</td>
<td>We have acknowledged the reviewer’s criticism by rephrasing k) accordingly.</td>
<td>The paper builds on the postulate that the system can smoothly readjust to its change and seems to neglect possible inelasticity. For instance, the investment required (Demsetz 1969) for a massive production shift from cereals, plant oils and so forth towards vegetables seems to have been neglected. Furthermore, no lowering factor for yields is adopted to take into account the readjustment time.</td>
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<td>I</td>
<td>I would support publication of this critique only if these elements of sniping can be toned down. A more valuable outcome would be for these experts to use their insight to modify the Badur paper by extending their own justified forecast(s) of what agricultural production and the human food spectrum may look in 2050. Perhaps it is salient that the critique documented here is called a &quot;sketch&quot; rather than a full published analysis that could be evaluated and used by those concerned about food security.</td>
<td>No sniping has taken place and proper academic rules have been followed in the elaboration of the present manuscript, which was originally submitted to the journal publishing the study being criticized. Only upon the journal’s rejection has the manuscript been submitted to <em>Food Ethics</em>. As clearly stated in our conclusions our objections are both technical and ethical, which make <em>Food Ethics</em> and appropriate venue for this debate, to which Badur and co-authors are welcome to further contribute.</td>
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The article does not quantify the odds for the described outcome nor expresses any concern about it. From an economic viewpoint the authors also underly the "fallacy of the free lunch"(Demsetz, 1969) which means that costs for achieving a better situation have been neglected.

We thank the referee for his/her helpful comment. The suggested reference has also been included in the relevant passage.

(Demsetz, 1969) added to k)

Badur et al. (2016) present questionable crisp numbers but leave no room for variations. Again, the

We have also incorporated this reflection in a) by making reference to the uncertainty of the provided estimate in Badur et al. (2016)

How can the hectares extension be given with three significant digits (438 millions)? The many assumptions feeding into the
A report should provide the likelihood of their very precise forecast. Here, aiming to provide a rough confidence interval around the predicted agricultural land reduction would be the better scientific approach.

Analysis would probably suggest a one digit precision. The most comprehensive database currently available, the FAOstat metadata (FAO, 2017), see [http://fenixservices.fao.org/faostat/static/documents/RL/RL_e.pdf](http://fenixservices.fao.org/faostat/static/documents/RL/RL_e.pdf) warns about the accuracy of the available data due to the lack of consistency and accounting method across countries. A quantification of the error and of the uncertainty in the output would have been appropriate.

It is hard to believe that a general education system for people from all over the world can be created. The different cultures all have their own traditions especially concerning food. Additionally, big parts of the world’s population cannot be affected by legislators. For example, there are still illiterate people and people without access to communication systems that are unapproachable, people from third-world countries living under inhumane circumstances and people that are influenced by stakeholders with strong interests in the production of unhealthy food, just to name a few.

On the one hand, big players of the industry will not stand by and watch an education system taking away their earnings, they will rather defend their share.

Also this point on lobbying has been acknowledged and included at point i) in the manuscript.

Finally, the role of possible agricultural-sector lobbies should have been better discussed at the planetary level.

On p.2 line 20 to 21 it is said that ”agriculture requires 438 million hectares less land than it did in 2010“. In the original paper as well as in the introduction on p.1 line 45 it says 2015.

The suggestion has been accepted and the manuscript edited accordingly.
On p.2 line 20 to 21 it is said that "agriculture requires 438 million hectares less land than it did in 2010". In the original paper as well as in the introduction on p.1 line 45 it says 2015. The suggestion has been accepted and the manuscript edited accordingly.

On p.2 line 14 to 15 it is written, "...Unlike previous measures this target specifically the "Global south". The conjugation here would be "targets". The suggestion has been accepted and the manuscript edited accordingly.

On p.2 line 43 to 44 it is stated that "...A quick look at the sources tells us that that total agricultural land...". This line has got two "that". The suggestion has been accepted and the manuscript edited accordingly.

**Reviewer #3**

i) The English language has been improved, ii) some restructuring has been performed and iii) superfluous text taken out as recommended by the reviewer.

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<th>Reviewer comments</th>
<th>Reply to the comment</th>
<th>Change in the manuscript</th>
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<td>1) What about sustainability? You mention this in the keywords, but it's never mentioned or discussed again. This needs to be introduced and discussed, as it is a central topic to future food systems, and the overarching theme of the 2030 Agenda, which will guide decision and policy making in the years to come.</td>
<td>We thank the referee for his/her comment. The issue of sustainability and the challenges a sustainable food-production systems poses have been addressed in the conclusions.</td>
<td>Ravetz’s insight is particularly appropriate in light of the ongoing discussion about sustainability of food systems - a central topic of the 2030 Agenda, which will guide decision and policy making in the years to come. Sustainability will need a hard look at power relationships, beyond the comfort of technical solutions.</td>
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<td>2) What about fresh water resources? Aside from the energy from the sun, water is the most fundamental issue for food production, be it</td>
<td>Very bold point! We are extremely grateful to the referee for this brilliant remark, we have incorporated a passage in the manuscript dealing with the issue. We have also made</td>
<td>An assessment of water use should have been produced as well. As water is primarily withdrawn and used in agriculture (Mekonnen and Hoekstra 2016; Dalin et al. 2017) its local scarcity could pose significant challenges for an effective coexistence of</td>
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animal or plant. If Badur et al. (2016) do not mention it in their article; you should raise this point in yours.

What about food waste management? Both the global north as well as the global south waste about 40% - albeit at different stages of the food system.

We doubt better food management could bring significant effects in developed countries due to the food-production system inelastic response for several by-products as well as the influence of the Jevons paradox (Polimeni et al., 2007). We believe the latter factor would also affect developing countries. By-products are typically overproduced due to the characteristics of the industrial processes in which they are made. E.g. butter is produced in amounts not affected by the demand level as it is largely a by-product of the dairy sector. This applies to many other food commodities as well. According to the Jevons paradox, the reduction in food waste would not bring to a reduction in food production. New markets would be simply sought out by food producers. Although we do not dare to attempt any quantification here, we believe the food-waste-reduction potential is largely overrated in the light of what discussed above.

Too vague, quantifications of what?

We agree with the referee and the title has been edited to accommodate the proposed correction.

Problematic quantifications: a critical appraisal of scenario making for a global ‘sustainable’ food production

P1 L 10. "the adoption of doubtful assumptions coupled with misleading quantifications" - what does this really mean?

Both the suggestions have been accepted and the abstract rephrased accordingly.

[Our contribution to this debate comes in the form of a critique of a paper recently published in the literature, Badur et al. (2016). In their work, the authors[...]}
| L11. Alternatively; | "as in the case of Badur et al. (2016)."
| L14. "...THE near future..." | The suggestion has been accepted and the manuscript edited accordingly.
| L44. "...that THE word population...», delete "on the planet" | The suggestion has been accepted and the manuscript edited accordingly.
| L49. Alternatively, "...a change in consumption patterns." | The suggestion has been accepted and the manuscript edited accordingly.
| P2 L15. Alternatively, "...this specifically targets the 'Global South'." | The suggestion has been accepted and the manuscript edited accordingly.
| P2 c) and d). These do not necessarily need to match up, because there is no 'perfect' match between people and food production, hence the food waste argument. And yields of what where? Here you are falling in the same trap as the paper you are critiquing; namely using hard numbers without qualifying their meaning. | We agree. The passages have been rephrased to take into account the raised points.
| P3 L26. "ARE made..." | The suggestion has been accepted and the manuscript edited accordingly.
| P5 L13-17. This is not part of your conclusion, but of your methods, and should be moved up, possibly to the intro. "The style of the critique presented in the present work borrows from the tradition of system ecology (Odum 1968), as well as from the more | The suggestion has been accepted and the manuscript edited accordingly.

Assuming it refers to an average figure, a one per cent increase in yield over the 35 years separating the authors from the 2050 gives a total increase in yield of e^{0.35} = 1.4. Applying this increased yield to the reduced area computed in (b) gives an overall increase in output of about 1.3.

Population has been assumed to increase from 7.4 billion (in the year 2015) to 10, corresponding to a factor of 1.3. Thus, the increase in output would merely balance the increase in population. This would assure the same average food availability at the global level as per today.
recent methods of sensitivity auditing (Saltelli and Funtowicz 2014) and quantitative storytelling (Saltelli and Giampietro 2016).

References


