Are our Visions of the Future Development Realistic?

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Introduction

The Grand Challenges of Humanity lying ahead besides technical solutions require behavioral changes. Thus, it is important that appropriate awareness on the influence is created, which each individual actually has. In a democratic environment only this awareness can avoid the tragedy of commons, i.e. the over-utilization of common resources because everybody has the impression that the individual influence is minor. To induce such awareness in citizens and policymakers, a tool that allows varying major influencing variables and that quantitatively simulates and represents the consequences on future development for each scenario chosen is desired.

Typically, the current scenarios for policymakers, e.g. those used as basis for the reports of the Intergovernmental Panel on Climate Change (IPCC), are generated with complex, so-called integrated assessment models (IAM). An IAM is solved in time-consuming simulations which depict the interplay between a multitude of influencing variables. That such complex simulation can fail to appropriately describe reality is well-known in chemical engineering (Hasse, 2003). Also, such complex simulations are not appropriate to give a quick feedback on variations of input variables in the course of exploring variations of scenarios. Thus the desired tool should be versatile and easy to apply.

Background and Tool

It turns out that on global level major dependencies for future development can be described with balances on materials and energy fluxes with only few assumptions. The amount of fossil resources utilized in the future define e.g. the quantity of carbon dioxide emitted, of which a known fraction ends up in the atmosphere causing a certain level of climate change. The overall energy demand can be evaluated from the growing number of humans inhabiting planet Earth and the average per-capita energy demand. Since fertile land area is required for food production as well as e.g. for supply of bio-energy an for BECCS (bio-energy with carbon capture and storage), the renewable energy transition is linked to agricultural productivity.

To develop scenarios for the future, only for a limited number of variables the past trends have to be projected into the future, like population growth, per-capita energy demand, and agricultural productivity (see Figure 1). Other key parameters are defined by the technology pathway we will realize as well as behavioral decisions. Such choices define, how quickly we increase the contribution of renewable energy, how much BECCS we implement, and bio-energy we use. Another key factor in the competition about land area is defined by the fraction of animal-based food we consume.

Since every consumption and waste production scales with world population, that variable deserves special consideration. Few sources are available that project population development into the future. Especially the World Population Prospects by the UN have frequently been updated. It had previously been realized that the updates regularly shift the projection towards higher values, as shown in Figure 2 (UN, 2020, Pfennig, 2019). Here the projections for the year 2050 are shown as they are published in different years for three variants of the projections. If that behavior is extrapolated, 11.6 billion is reached in 2050. The projections of Lutz et al. (2014, 2018) lie somewhat below, but unfortunately also their update is shifted upwards in a very comparable manner. Thus, both projections, which build on slightly different assumptions, show an identical trend. This is fatal, because the current projections for the IPCCs 6th Assessment Report to be published 2022 utilize the population scenarios, the so-called SSPs (shared socio-economic pathways), which were published by Lutz et al in 2013. The extrapolation lies even above the updated worst-case SSP3 scenario. Thus, the current projections are foreseeably too low, i.e. too optimistic, which means that they underestimate resource consumption and CO_2 production. Thus, the current scenarios are obsolete already today. As a consequence e.g. the severe competition for land area is not properly predicted.

To achieve the goal of having a versatile and responsive scenario tool available, all the required dependencies and projections have been collected and compiled into an excel spreadsheet, which is available at www.vision3000.eu. This tool allows to easily vary those variables that correspond to choices to be made by sliders. It is especially possible to also account for DACC (direct air carbon capture), i.e. the removal of carbon dioxide directly from air with appropriate sorption processes. DACC is considered as one option to obtain a sustainable carbon source for the chemical industry, e.g. by DECHEMA (2019). Unfortunately DACC is extremely resource consuming, because just recovering the CO_2 without any conversions requires roughly 2.5 to above 3 times more energy than has been gained by producing it in brown-coal fired power plants (Keith et al., 2018). At the same time, the sorption technologies until now have not been validated at larger scale, so that they are still far from being established technology on the appropriate scale. This suggests that utilizing bio-based feedstock may be more suitable, even though it requires more fertile land area. The simulations show that sufficient food supply is nevertheless possible, while meeting essentially all demands for a sustainable global economy, including reducing climate change to below 1.5 °C by 2100, and based on existing and available technology – but only, if animal-based food is essentially avoided. Such a scenario for land-area utilization is shown in Figure 3.

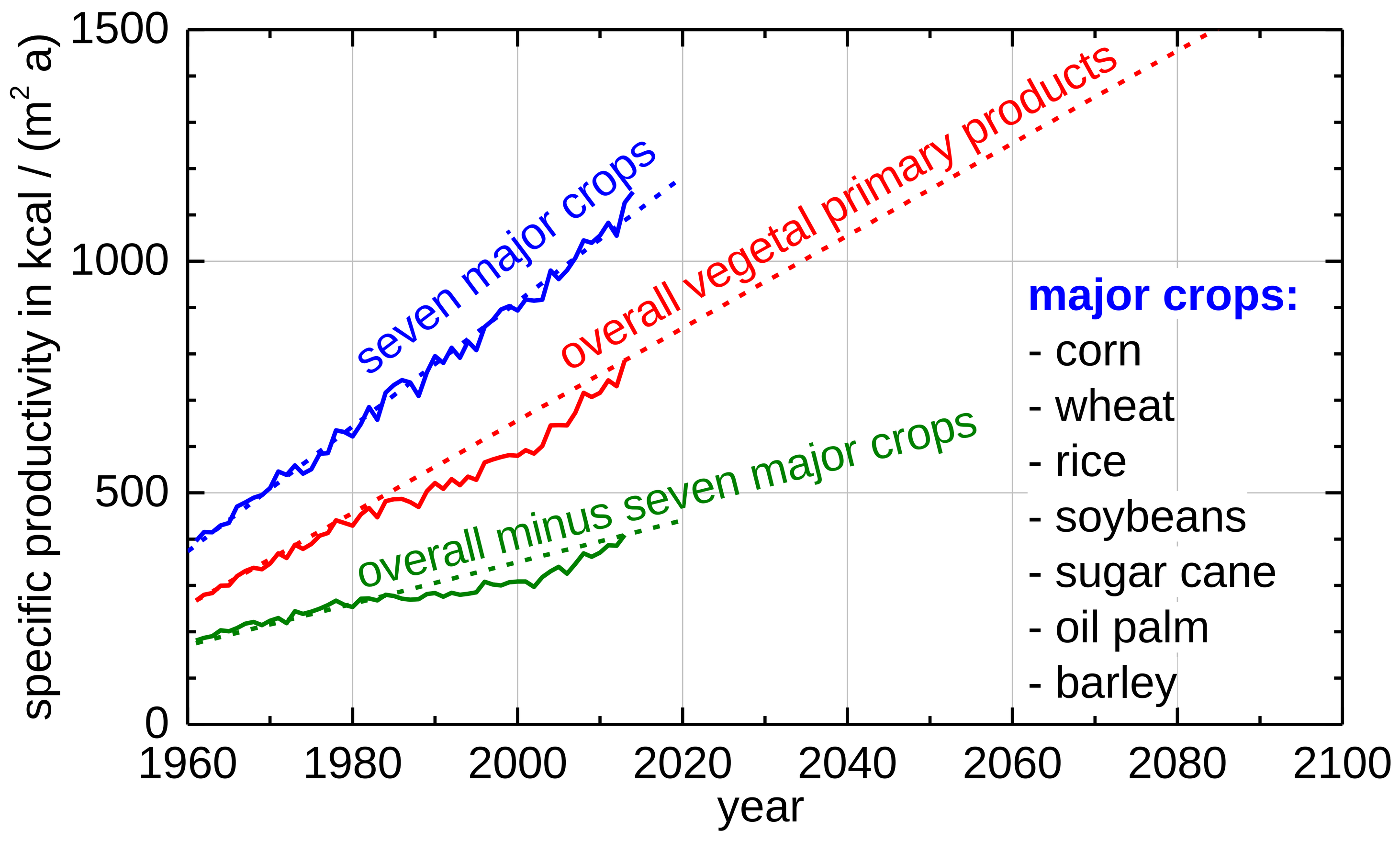

Figure 1: It is assumed that the agricultural land-area specific productivity increases linearly in the future as it did in the past

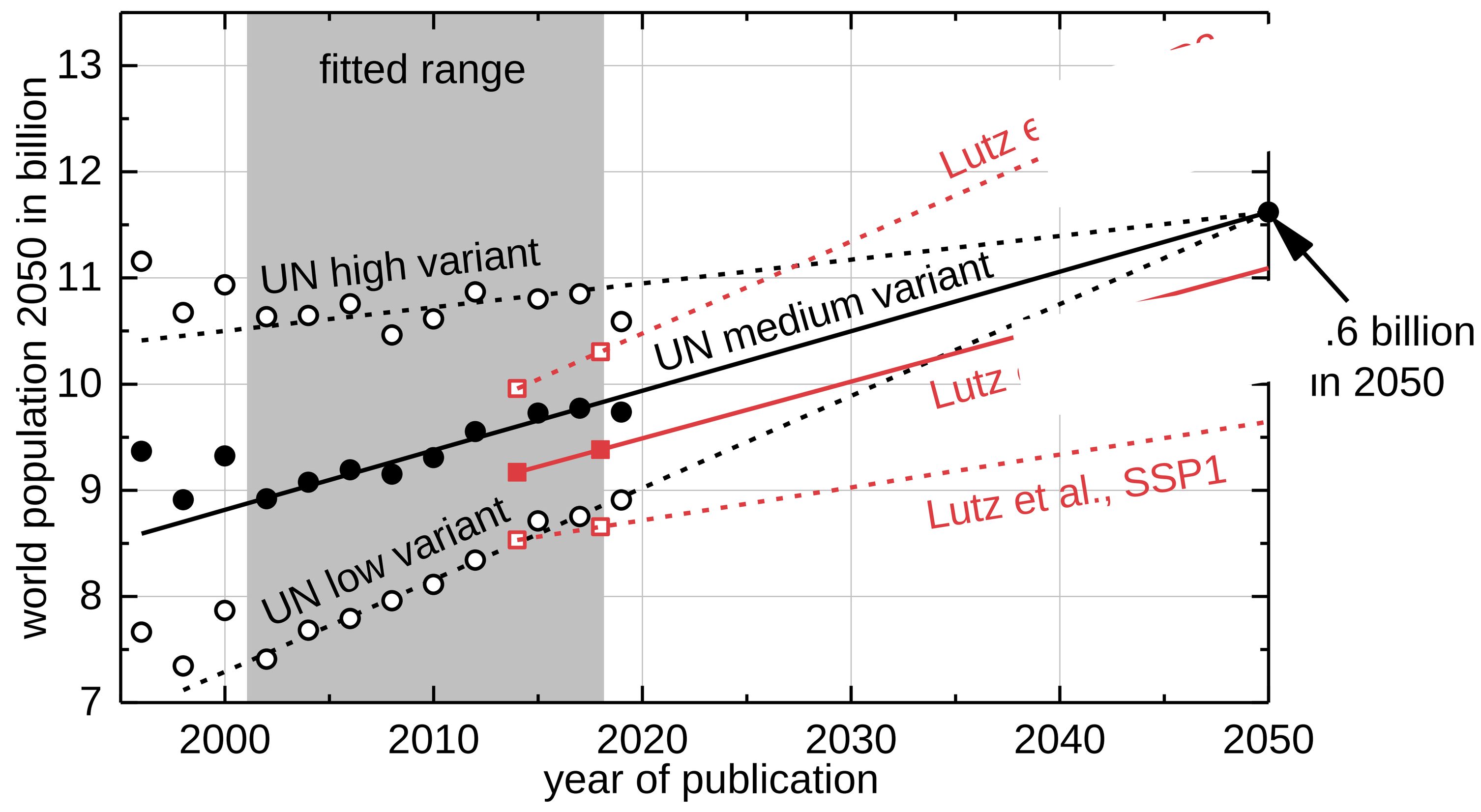

Figure 2. Predicting development of world population has always been corrected in upward direction: possibly above 11 billion are expected in 2050 instead of the current estimate of 9.8 billion (fitted range shown in grey)

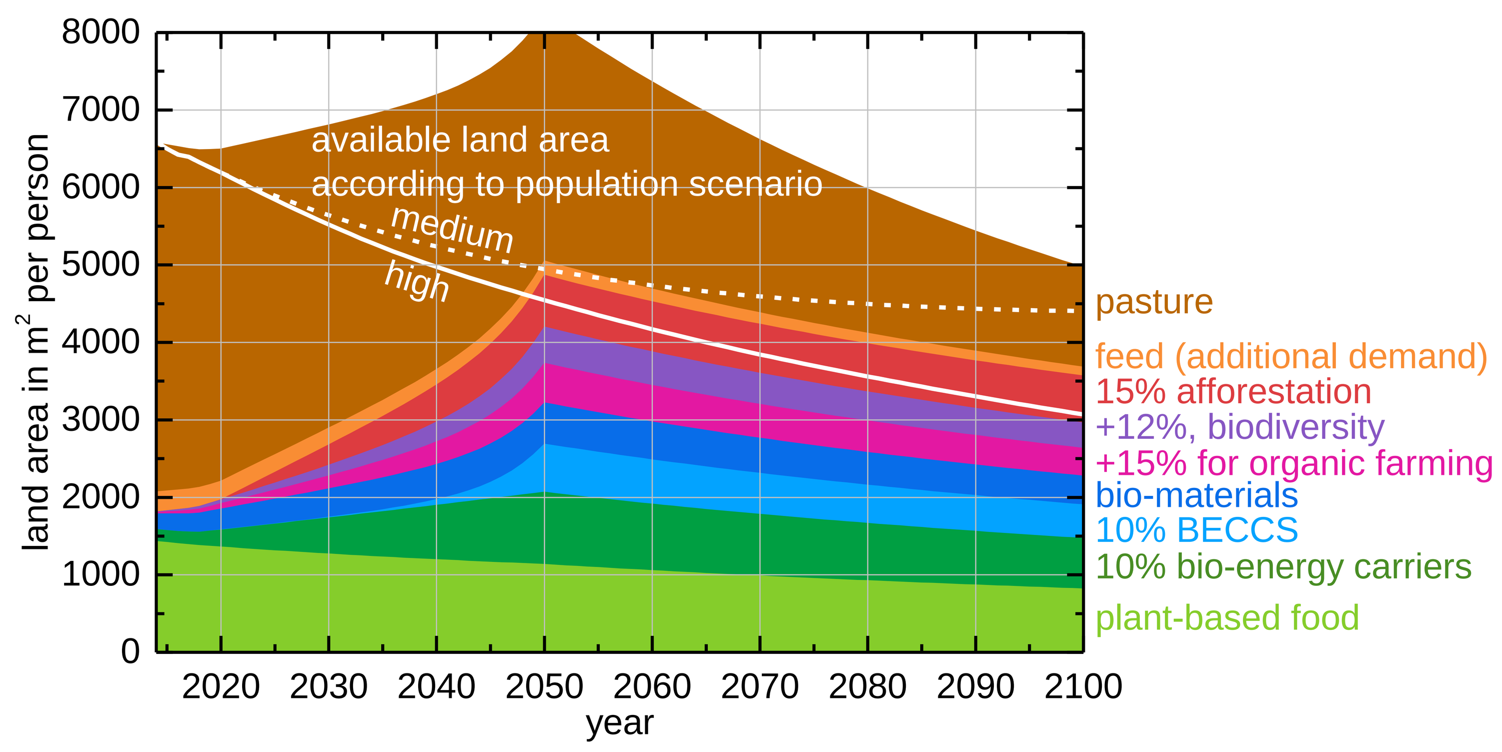

Figure 3: Fertile land area required for different purposes compared to the available area showing that with the future demands, we lack sufficient fertile land area. The kink in 2050 results from assuming that by then the transitions are completed.

Conclusions

The scenario analysis with the balance-based tool derived allows evaluating a variety of scenarios. The evaluations show that fertile land area is a scarce resource. They also suggest that the demands can sustainably be fulfilled with available technology, if renewable energy transition is significantly speeded up, if population growth is limited by supporting poorer countries in their economic development, and nutrition is shifted to essentially solely plant based.

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