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Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures

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ABSTRACT

Both supply and demand side changes are necessary to achieve a sustainable food system. However, the weight accorded to these depends on one's view of what the priority goals are for the food system and the extent to which production systems *versus* consumption patterns are open to change. Some stakeholders see the problem as one of 'not enough food' and focus on the need to sustainably increase supply, while others consider the resource demanding and 'greedy' consumption patterns of the Western world as the main problem and emphasize the need to shift diets. In this study global land use and greenhouse gas emissions are estimated for a set of scenarios, building on four 'livestock futures' reflecting these different perspectives. These scenarios are: further intensification of livestock systems; a transition to plant-based eating; a move towards artificial meat and dairy; and a future in which livestock production is restricted to the use of 'ecological leftovers' *i.e.* grass from pastures, food waste and food and agricultural byproducts. Two dietary variants for each scenario are modelled: 1) a projected diet following current trends and 2) a healthy diet with more fruits and vegetables and fewer animal products, vegetable oils and sugar. Livestock production in all scenarios (except the baseline scenario) was assumed to intensify to current levels of intensive production in North-Western Europe. For each scenario, several variant assumptions about yield increases and waste reductions were modelled. Results show that without improvements in crop productivity or reductions on today's waste levels available cropland will only suffice if production of all protein currently supplied by animal foods is replaced by (hypothetical) artificial variants not requiring any land. With livestock intensities corresponding to current ones in North-Western Europe and with yield gaps closed by 50% and waste reduced by 50%, available cropland will suffice for all scenarios that include a reduction of animal products and/or a transition to poultry or aquaculture. However, in the scenario based on an extrapolation of current consumption patterns (animal product amounts and types consumed in proportions corresponding to the current average consumption in different world regions) and with livestock production based on feed from cropland, available cropland will not be enough. The scenario that makes use of pastures for ruminant production and food waste for pigs, uses considerably less cropland and could provide 40–56 kg per capita per year of red meat. However, such a livestock future would not reduce GHG emissions from agriculture on current levels. This study confirms previous research that to achieve a sustainable food future, action is needed on all fronts; improved supply and reduced demand and waste.

1. Introduction

The current food system is a major driver of environmental pressures (Foley et al., 2005, 2011). The total environmental impact of food consumption depends on the 1) size of the human population, 2) the per capita consumption of food (eaten and wasted), and 3) the impact per kg (or kcal) of food produced, transport, distributed and ultimately disposed of. The global population is expected to reach 9–11 billion by 2050 (UN, 2012). Tackling population growth is one route to reducing food security pressures and addressing environmental concerns (The

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Royal Society, 2012). However, much of the projected population increase is unavoidable due to the population-lag effect, and the issue has historically been sensitive for political and religious reasons. Consequently efforts to reduce food-related environmental impacts have mainly focused on improving food production and reducing its impacts, with attention more recently turning to altering resource-intensive food consumption patterns (Smith et al., 2013). However, which of these factors, production or consumption that is prioritized depends on one's view on what the most urgent goals are for the food system and the extent to which production systems *versus* consumption patterns are seen to be malleable and open to change (Garnett, 2014).

As regards food *consumption*, a combination of population growth and increased affluence has led to a rapid aggregate and *per capita* increase in the supply and consumption of animal products (Kearney, 2010), which generate high environmental burdens (Westhoek et al., 2014). Some stakeholders, including those from the food and farming industries, research institutes and policymakers, see this increase in demand as inevitable or at least a distinct possibility for which preparation to meet this demand is needed. For these groups, the problem to be addressed is 'not enough food' and as such they focus on the need to increase supply for our growing and increasingly wealthy global population (Garnett, 2015). In order to address environmental pressures, production-side technological advances and efficiency that achieve more with reduced impacts per unit of food output are viewed as key. Sustainable intensification is a term that has been coined to describe this concept (Garnett et al., 2013; Smith, 2013; The Royal Society, 2009).

Other groups, including animal rights and environment NGOs, as well as some academics drawn from environmental, nutrition or social science disciplines, see the increasing demand for animal products and other resource-demanding and unhealthy foods as a focal concern. Their analysis sees the problem as one of 'too much greed' (Garnett, 2015) *i.e.* the consumption patterns of the Western world are catastrophically resource intensive and the priority should thus be to address them. This narrative places emphasis on the high environmental footprint of animal products and the perceived inefficiency of feeding grain and other human edible products to animals.

Following these perspectives, different mitigation options are emphasized. Productionist advocates of the 'not enough food' world view urge increased efforts to close yield gaps in crop production and to intensify livestock production, in order to produce more food using less land, water, energy and fertilizers. Proposed mitigation options include improved manure management with *e.g.* biogas production, breeding, feed additives to reduce methane production in ruminants and bioenergy-fueled buildings and machinery (Smith et al., 2008a,b), as well as technologies capable of extracting as much edible and non-edible value as possible from the slaughtered animal (Newton et al., 2014).

Proponents of demand-side changes on the other hand, focus on dietary shift: specifically on the need to reduce overconsumption, alter, decrease or eliminate consumption of animal products, through transitioning to alternatives with lower impact – variously or including poultry (Hoolohan et al., 2013), aquaculture (Roberts et al., 2015), artificial meat/milk (Post, 2012) or plant-based protein (Popp et al., 2010; Stehfest et al., 2009; Wirsenius et al., 2010.

A third narrative centres on the imbalanced power/socio-economic relations among food system actors (Garnett, 2015) and in our relationship with the natural world. For proponents of this approach, the priority is to 'rebalance' the system which expresses itself in advocacy of more 'balanced' or nature-mimicking farming systems. In this paper we call this perspective 'too imbalanced'. Livestock are seen as integral to this balancing act through their ability to recycle nutrients and utilising marginal land and by-products and turning these inedibles into nutritious food for humans. Livestock-including production systems based on organic principles, often with a strong emphasis on grazing, are seen as an integral part of the solution, with animal numbers limited to what the local resource base can maintain.

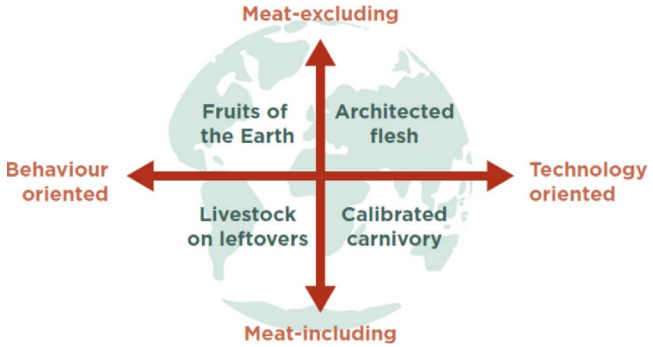

Fig. 1. Four scenarios for livestock futures. From Garnett (2015).

Of course these are overly simplistic representations of different viewpoints, and most people or institutions will span different perspectives. Recent research has begun to blur the dividing line between these narratives. A growing number of often interdisciplinary studies, include and advocate the need for both production-side mitigation options, and demand reductions (Bajželj et al., 2014; Davis et al., 2016; Erb et al., 2016; Godfray et al., 2010; Popp et al., 2010; Smith et al., 2013; The Royal Society, 2009; Tilman and Clark, 2014). For example, Godfray and Garnett (2014) strongly argue that sustainable intensification approaches need to go hand in hand with measures to address diet, tackle population growth and improve equity of access. Whatever perspectives, stakeholders are generally united on the need to reduce the 30–40% of food that is lost or wasted along the food supply chain (FAO, 2011; IMECHE, 2012).

Based on these different viewpoints, *i.e.* on what lies at the root of the food system's problems, and how these problems should be addressed, Garnett (2015) outlined four hypothetical future scenarios for future livestock production and consumption (Fig. 1). These scenarios vary in their inclusion or exclusion of farmed meat, and in the emphasis they place on the mitigation potential of behaviour (changes in demand) versus technology (production improvements) – mirroring the three perspectives of 'not enough food', 'too much greed' and 'too imbalanced'. A brief description is as follows.

'Fruit of the Earth' is a meat-excluding, behaviour-oriented scenario, where global public and policy acceptance of the need to radically alter diets leads to a shift to a mainly plant-based diet. In a second scenario, 'Architected flesh', growing demand for meat is seen as inevitable and met not by conventional animal production but through in-vitro artificial meat production, based on assumed high rapid technological development in this area. In 'Calibrated carnivory', growing demand for animal products is likewise seen as inevitable and is met through widespread adoption of highly intensive poultry, dairy and aquaculture production systems, whose overall efficiency is expected to compensate for the increased demand. Finally, the 'Livestock on leftovers' stems from the third narrative described above of 'too imbalanced'. Here farm animals in the right systems and right scale are seen as an integral part of environmental sustainability by turning biomass from marginal land and food waste into human edible foods. Therefore, this scenario sees a radically different future for livestock farming: animal production is limited to the level supportable from land unsuited to crop production and food and agricultural residues. This avoids competition between food and feed (Garnett, 2009; Röös et al., 2015; Schader et al., 2015). Consumption of animal products is restricted to the levels that these 'leftover' resources can provide.

This study quantifies agricultural land requirements and greenhouse gas (GHG) emissions arising from these different hypothetical livestock future scenarios in 2050 to provide more substance to the discussion on implications from different mitigation options. We model these scenarios for both projected diets and an example 'healthy diet' to show how potential dietary shift would affect land use and emissions. It is assumed that production-side mitigation options and actions to reduce