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Three perspectives on sustainable food security: efficiency, demand restraint, food system transformation. What role for life cycle assessment?

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ABSTRACT

Achieving food system sustainability is a global priority but there are different views on how it might be achieved. Broadly three perspectives are emerging, defined here as: efficiency oriented, demand restraint and food system transformation. These reflect different conceptualisations on what is practically achievable, and what is desirable, underpinned by different values and ideologies about the role of technology, our relationship with nature and fundamentally what is meant by a 'good life.' This paper describes these emerging perspectives and explores their underlying values; highlights LCA's role in shaping these perspectives; and considers how LCA could be oriented to clarify thinking and advance policy-relevant knowledge. It argues that more work is needed to understand the values underlying different approaches to the food sustainability problem. This can shed light on why stakeholders disagree, where there are genuine misunderstandings, and where common ground is possible and ways forward agreed.

1. Introduction

The food 'problem' has become a global obsession. How much and what kind of food is produced, how and by whom; how it is moved, processed, packaged and sold and with what impacts; who gets what and how much to eat, and at the expense of whom – and what the future might hold for all these variables; these questions are now the subject of measurement, analysis, critique and campaigning in research journals, policy documents, newspapers and television screens worldwide.

As such, the scale of the problems we face and their relationship with the food system are now well recognised and have been exhaustively described elsewhere (Godfray et al., 2010; Beddington et al., 2011; Foresight, 2011). Put briefly: our global population is rapidly growing, urbanising and becoming wealthier, one consequence being that our dietary patterns are changing and our demand for land, resource and greenhouse gas (GHG) intensive foods, such as meat and dairy products, is on the increase. But while the demands we place on the earth may be growing, its available resources – of land, water, minerals – are finite. The difficulties presented by this demand-supply imbalance are compounded by changing environmental conditions which make food production increasingly difficult or unpredictable in many regions of the world; and production systems that not only undermine aspects of the ecosystem, such as biodiversity and water quality, upon which we ultimately depend, but also exacerbate zoonotic diseases and other risks that directly affect our health. Perhaps most starkly, inequities and distortions in how both the inputs to and outputs from food production are distributed have given rise to a paradoxical situation wherein 1.4 billion people world wide are overweight or obese, while 850 million lack sufficient calories and are undernourished (Swinburn et al., 2011; FAO, 2011). The challenge is therefore to refashion the food system to deliver better nutritional outcomes at less environmental cost. But while this much is clear, the proposed solutions have been less coherently articulated and are certainly more contested. Stakeholders - across and within the food industry, civil society, policy makers and the research community – have often strikingly different views on what should be done.

It is argued here that broadly three perspectives are emerging in the debate on food system sustainability today. These in turn reflect different conceptualisations as to what is practically achievable given the variables of technological innovation, the functioning of the global economy and human motivations and behaviour – as well as different visions of what a sustainable food system actually looks like. These are in turn underpinned by different values and ideologies about the role of technology, our relationship with nature and fundamentally of what is meant by a 'good life.'

The purpose of this paper is threefold: to describe these three emerging perspectives on the nutrition-environment challenge

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and explore their underlying values; to highlight the role that life cycle assessment (LCA) has played in shaping these perspectives; and finally, to consider how LCA could be oriented and utilised in ways that clarify thinking and help advance policy-relevant knowledge in this field. It should be emphasised that, except at the extremes, these perspectives are not rigid and mutually exclusive. There will often be overlap between them and they are perhaps better viewed as ideological 'tendencies' rather than closed belief systems. The research community is represented across all three approaches.

2. Perspectives on achieving food system sustainability

The three approaches are defined as follows: efficiency oriented; demand restraint perspective; and food system transformation.

2.1. Efficiency

This is perhaps the dominant approach. Its advocates include governments and food industry actors such as agricultural input businesses, farming unions, manufacturers and retailers. In essence this perspective is based on the assumption that the food security problem is a supply side challenge. More food needs to be produced to meet increasing and changing demand by growing populations; technological innovations and managerial improvements will enable us meet this demand in ways that impact less harmfully upon the environment while also enhancing nutrition (ADAS et al., 2011).

Agricultural efficiencies can be achieved by, for example, optimising the timing and quantity of fertilisers applied, using drip irrigation and other precision agriculture techniques and deploying technologies, such as anaerobic digestion, that recover utility from agricultural waste (manure, crop residues). Productivity increases in livestock can reduce emissions per unit of production, with approaches including: breeding for higher yields (of meat, milk or eggs), formulating feeds to maximise yields while minimising nitrogen or methane losses, and developing housing systems that optimise conditions for growth (Garnett, 2011). Post harvest, emissions can be reduced through adoption of refrigeration, manufacturing and transport technologies that are more energy efficient or based on renewable energy sources. Waste is minimised through better inventory management, by modifying packaging and portion sizes and through other approaches that either prolong the shelf life of foods or help consumers reduce food waste in other ways (WRAP, 2012).

While this perspective does not explicitly argue for this approach on moral grounds, it is nevertheless underpinned by a moral framework and a set of values: these give rise not only to a vision of what constitutes progress for humanity but also to an optimism that it can be achieved. Within this perspective, a strong component of a good life is one in which more people will achieve the material comforts enjoyed by affluent consumers in the developing world today – but with less environmental impact. Using technology, the boundaries of our environmental limits can be extended to accommodate us and, provided the right market signals are in place, the global economy will enable both the material and environmental benefits to trickle down to all sectors of society.

LCA's influence on this approach has been critical. LCAs have helped companies identify environmental hotspots in the supply chain, reassess 'common sense' assumptions that (for example) locally sourced, or organic food has a lower environmental impact, and identify foods with the most significant impact. (Williams et al., 2006; Edwards-Jones et al., 2008; Sim et al., 2007; Defra, 2008; FAO, 2010b; Nemecek et al., 2012) As recognition of the contribution that agriculturally induced land use change makes to food's GHG emissions has grown, (Burney et al., 2010; FAO, 2006) so the need to raise productivity so as to 'spare' land from further agricultural encroachment and associated CO2 release is emphasised.

However the LCA approach has not just informed this perspective but has also been influenced by it – or rather the use of LCA has helped strengthen the efficiency mindset. For example, it generally draws upon attributional LCAs where like product is compared with like and an alternative consumption possibility is not considered. Through this lens, Spanish lettuces are compared with, and found to be environmentally preferable to British lettuces grown under glass out of season. The desirability of consuming lettuces out of season is not considered, nor are comparisons made between lettuces and a more seasonal substitute food, such as cabbage. Similarly for meat and dairy; the carbon footprint of meat or milk production needs to be reduced, but demand for meat or milk per se is not questioned (IDF, 2009). Notably, the metrics used are relative – impacts are expressed as GHGs per unit of production, not per absolute quantity produced or consumed. This choice of relative metrics suggests implicit endorsement of an economic model predicated on growth, and on the primacy of consumer choice.

The problem of food waste is illustrative. Wasted food represents not only a waste of embedded GHG emissions and a threat to food security but, often, a financial inefficiency (Parfitt et al., 2010; WRAP, 2009; UNEP, 2009). Reducing waste therefore saves money: triple wins are possible. Implicit in this analysis of waste is the assumption that if less food were wasted this could have a role in addressing both GHGs and food security (WRAP, 2011; Gustavsson et al., 2011; United Nations, 2012). However there is less recognition of the porous boundary between food and other economic sectors, nor of the non-supply related causes of hunger. Sufficient quantities of food on the market per se by no means guarantees food security (Sen, 1981) an observation that motivates some to argue for more systemic approaches to addressing the food challenge (below). As regards the interaction between food and other sectors, businesses may diversify into non-food products, all of which carry an associated carbon footprint – and indeed this is often an explicit goal for many companies (Tesco, 2012). Consumers may use their saved money to buy other products or services that have an environmental impact, at least partially offsetting the emission reductions. In short, there is a rebound effect; relative improvements in efficiency may be partly or wholly offset by increased emissions in other sectors (Druckman et al., 2011). From a demand restraint perspective (discussed below) this underlines the need to address consumption per se, of which food behaviours are just one component (Jackson, 2010).

For biodiversity, the priority is to avert further land use conversion to agriculture. Intellectual support is provided by model-based research showing that, for a given agricultural yield and a defined land area, more intensive agricultural practices support greater biodiversity than less intensive 'wildlife friendly' production, since a dedicated block of land can be set aside purely for wildlife (Phalan et al., 2011). While the latter system may foster greater biodiversity on farm, more land is needed to produce a given quantity of food, and so land available for wilderness is reduced. Moreover the species supported in wildlife friendly farming are of lesser conservation interest than those found on virgin land. The strength of this approach is that it underlines the importance of addressing the knock-on effects of different agricultural systems on land use elsewhere – in essence a 'spatial rebound effect'. It is already used to consider the impacts of biofuels (Searchinger et al., 2008) but is starting to be more comprehensively applied to understanding food production systems too.

However, while this approach delivers a theoretical insight into the relative benefits for biodiversity of different farming systems, less attention may be paid to the socio-economic context within which farming is practiced. Critics suggest that the economics of high yielding production create incentives to expand production into ‘spared’ land to increase profits further, thereby undermining the theoretical benefits (Fischer et al., 2011) an issue returned to below. Hence while as noted, this perspective implicitly endorses a growth-based economic model in other respects, it does not consider how the workings of the market might actually affect land sparing approaches in practice.

Regarding food security and nutrition, the two are considered somewhat separately within the efficiency mindset. The food security challenge is seen as one of increasing production to meet demand, with demand projections based on assumptions about income growth and its relationship with demand for certain foods, such as meat (Conforti, 2011; Tilman et al., 2011; Foley et al., 2011). Less attention is paid to other dimensions of food security (access, utilisation, stability over time) (FAO, 2008) or to the nutritional quality of food.

Moreover, the efficiency approach tends to shy away from saying what people should or should not be ‘demanding’ either for environmental reasons (as noted) or for health. Just as GHG efficiencies can be achieved using the insights from LCA to target environmental hotspots in the supply chain, so ‘health efficiencies’ are to be secured through product reformulations that deliver foods similar in taste to the originals but, for example, lower in fat, sugar or salt or with enhanced nutrition (such as prebiotics or omega 3 fatty acids). Supported by appropriate information, the consumer is then free to choose the healthier option without fundamentally needing to change her or his diet.

As regards animal products – criticised both on environmental and nutritional grounds by others (below) – the efficiency perspective is more positive, arguing, for instance, that milk delivers greater value per environmental impact than many other beverages. It points to research concluding that, for a combination of nutrients delivered per unit of GHGs emitted, low fat milk represents better nutritional ‘value for climate’ than orange juice, milk substitutes and others (Smedman et al., 2010; ICUSD, 2010). Notably, low fat milk is chosen as the subject for analysis. While the removed fat might be incorporated into another product (a cake, say) the nutrient-climate impact of that product is not considered; a system expansion LCA approach might therefore yield different results. The emphasis, again, is on relative merits and there is no further analysis of what an ‘optimal’ level of consumption might look like – the minimum quantity of milk needed to deliver nutritional benefits without incurring excessive GHG cost through ‘unnecessary’ consumption, surplus to requirements.

In low income countries, the nutritional priority is to address micronutrient deficiencies. Food fortification (post harvest) and biofortification (breeding crops higher in target nutrients) are strategies that resonate with the efficiency perspective (HarvestPlus, undated), since they offer a technical way forward. Biofortification is considered particularly promising: while initial research investment costs are high, ex ante assessments suggest their cost effectiveness in addressing deficiencies is even greater. (Meenakshi et al., 2010). The approach, however has been criticised by the systems perspective as over-simplistic (below).

2.2. Demand restraint

For the efficiency mindset, the onus is on producers to develop appropriate techniques and strategies to reduce emissions; for the demand restraint perspective however, the problem lies with the consumer and with the companies who promote unsustainable consumption patterns. The end point in the supply chain – the consumer – becomes the focus of concern. Central to this perspective lies the conviction that excessive consumption is a leading cause of the environmental crisis we face. Its vision of change is therefore an overtly moral one: it explicitly criticises the status quo rather than – for reasons that may also be morally motivated but less explicit – endorsing it.

The priority is to curb consumption of high impact foods. While in the 1990s the focus was particularly on foods high in ‘food miles’, as the findings of LCA research filtered through to the environmental community, combined with accusations of being ‘anti poor’ from poverty organisations, (MacGregor and Vorley, 2006), the locus of concern then shifted to animal products. The FAO's seminal *Long Shadow* report (FAO, 2006) and numerous LCA-inspired scientific and NGO publications have highlighted the heavy burden that livestock place on land, water, biodiversity – and their contribution to GHG emissions (Pelletier and Tyedmers, 2010; EC, 2006; Weber and Matthews, 2008; Stehfest et al., 2009; McAlpine et al., 2009).

Thus, while the efficiency perspective uses LCA to identify opportunities where technology and management can improve production efficiency to reduce the relative ‘footprint’ of existing consumption patterns, the demand restraint approach targets the consumption habits that ultimately drive production (they may also argue that the producers are seeking to generate the demand in the first place). This perspective also focuses on investigating alternatives to the status quo, should consumption patterns change. Thus it draws not only upon attributional ‘snapshot’ LCAs that identify the most GHG intensive foods but also on those that adopt a ‘what if?’ approach to considering alternative scenarios. Increasingly, there is a focus on the opportunity cost and missed carbon sequestration potential arising from livestock production – it is argued that, if this land were not used for livestock it could regenerate naturally, or be used for other carbon sequestering purposes (Audsley et al., 2009; Schmidinger and Stehfest, 2012). In other words, while the efficiency perspective looks at the implications for land use of different *production* systems (extensive versus intensive) the demand restraint perspective complements this by considering different *consumption* patterns.

For this perspective, the climate challenge is not separate from that of biodiversity or nutrition. They are all connected (CIWF, 2009; Hamerschlag, 2011). Livestock are not only dominant GHG contributors but also the main driver of land use change, deforestation and associated biodiversity loss; and they are associated with the rise in obesity and associated chronic diseases too (Popkin and Gordon-Larsen, 2004; Sinha et al., 2009; FOE, 2010; Pan et al., 2012). Other ethical and environmental concerns are added to the mix, such as water use and pollution, animal welfare (confined livestock in industrial scale units are a particular target) and working conditions. Unlike the efficiency perspective, where technology holds the promise of expanding or overcoming environmental limits, for this perspective technology is at times problematic, limits are absolute and humans are, essentially, damaging. Nature is not to be managed by humans – rather humans need to ‘get out of nature.’ This, arguably, is a darker, more misanthropic view of our relationship with the natural world, although to an extent both it and the efficiency perspective view nature as other – to be ‘spared’ for conservation without human influence.

Regarding nutrition and food security, this perspective draws upon an emerging body of LCAs examining the relationship between environmental and nutritional goals. Studies, which tend to focus on developed countries, whose citizens typically enjoy access to a diverse range of plant foods, generally show that plant based diets can supply an adequate balance of nutrients at lower GHG ‘cost’ than meat-dominated diets. (WWF, 2011; Carlsson-Kanyama and González, 2009; Davis et al., 2010) In contrast with the efficiency perspective it focuses less on the positive nutrients found in animal products, such as calcium, iron and zinc, that are of critical importance to people on low income in the developing world, particularly children (Dror and Allen, 2011). Hence, these perspectives draw upon different metrics to assess the nutrition-GHG relationship; one to endorse the status quo and the other to challenge it and to offer a different vision of how we ought to consume.

Much is made, by restraint advocates, of the point that there is enough food in the world to feed everyone, in contrast with the 'more food' emphasis in the efficiency perspective. The challenge is therefore to address inequitable and resource-intensive consumption patterns (Soil Association, 2010), but a sophisticated analysis of how structural inequalities might be addressed is lacking. For example, the feeding of grains to livestock is identified as a 'waste' since these could be more efficiently consumed directly by humans (UNEP, 2009) although some models find that due to global commodity price dynamics the effect on hunger reduction would be muted. Some argue that reductions in cereal prices would be partially offset by increases in prices of other foods, while lack of demand from the livestock sector would reduce farmers' incentives to grow the crops in the first place (Rosegrant et al., 1999; Msangi and Rosegrant, 2011). Just as the first perspective's optimism about technological 'efficiency' may be undermined by the rebound effect (discussed above), so 'efficient' consumption patterns, defined here by the restraint community as one of not feeding grains to livestock, may not translate into substantially greater food availability and affordability for the poor. Both ideological approaches are based on views about the way the world ought to work to ensure environmental benefits rather than the way it actually works, given current conditions.

In short, the word 'efficiency' is used differently by the two perspectives. While the efficiency perspective concludes that since grain fed livestock have a lower GHG footprint then those fed on grass and byproducts inedible to humans (Pelletier et al., 2010) they are more efficient, the demand restraint approach uses LCA to highlight precisely the opposite: from a consumption perspective the eating of grain-fed livestock products is less efficient, in terms of "GHG −per nutrient consumed," than eating grains directly.

2.3. Food system transformation

The production efficiency focuses on changing patterns of production; the demand restraint perspective on excessive consumption. The food system transformation perspective considers both production and consumption in terms of the relationships among actors in the food system, interpreting the problem as one of inequality or imbalance. This 'imbalance' in relationships gives rise to the twin problems of excess and insufficiency that are played out both in the environment (over- as well as under-application of agricultural inputs) and in relation to health (obesity and hunger).

Within this perspective can be found a broad spectrum of opinions, some more radical than others in their analysis of the problems and their vision of the solutions. For all, though, the central argument here is that the problems we face are socio-economic rather than simply technical or a consequence of individual decisions. Environmental sustainability can only be achieved through structural change (IAAKSTD, 2009; Foresight, 2011; Oxfam, 2011). At its ethical heart lies an emphasis on social justice — on the moral necessity of developing systems of production and consumption that explicitly address the needs of poor people. It shares with the demand restraint perspective a moral explicitness, but the emphasis is on the responsibility of the *system* to deliver the desired objectives rather than on the individual. In common with the efficiency perspective it says little about what the limits to growth might be — for many although not all within this perspective, growth at least in developing countries is implicitly a good thing — but it questions the ability of the market, as it stands, to deliver benefits equitably.

How does this view engage with LCA methodologies and findings? By its very nature, an analysis of the problem that sees causes and outcomes as multiple and interacting will not accept the use of simple or single metrics to assess impacts or progress, since such metrics fail to capture relationships among the different components of the food system over space and time. This means that LCA has so far had limited resonance with this perspective, and indicators against which to measure progress have not yet been developed. How far they can be is indeed a matter for debate.

To illustrate: since agricultural production and its sustainability, for this perspective, is very clearly about more than just the production of a given commodity, a simple functional unit such as kg CO2 eq/kg product will be an inadequate measure of the system's success in delivering outputs relative to environmental impact. Outputs from the system include not just products with market or food energy value (wheat, maize, rice, milk) but may, depending on context, also include micronutrients (especially important in low income settings), fibres for roofing, cooking fuels (timber, manure), animal traction, cultural identity and status and — as for livestock in developing countries - portable liquid assets that can be sold in times of need, such as sickness, or to pay for school fees. For many smallholders, the system's resilience may also be a desired 'output.' Where access to formal insurance is lacking, this may be achieved by cultivating a diverse range of crops. While sub-optimal from a CO2 eq/kg perspective, it can be essential for farmers who cannot afford to risk investing land and resources in producing just one high yielding commodity that may be vulnerable to pests or other shocks. More diverse multi-species systems (such as agroforestry) or mixed crop-livestock systems may represent more economically sustainable approaches. Whether they are also environmentally more sustainable depends on whether people consume only what is produced locally; if not, shortfalls in supply may be met by external purchases, whose production will have had environmental effects elsewhere, or else lead to other changes — such as a move to the city to find jobs — that have GHG implications, positive or negative. In short, from the systems transformation perspective the environmental impacts of a production system cannot be assessed without understanding the socio-economic context of production and consumption and the extent to which environmental impacts can be transferred, as it were, from one area or sector to another.

Mainstream LCA conclusions about different livestock systems are particularly open to question here since meat or milk, while clearly a desired output, is not the only one, nor is sheer volume of production the only goal. Table 1 illustrates how the choice of a different functional unit for a given livestock production system may alter conclusions as to its sustainability even when considering GHGs alone.

Alongside the challenge to mainstream LCA conclusions on livestock, a substantial subset from this perspective argues for more localised food production, despite the weight of LCA research concluding that transport distance does not correlate well with environmental impact, at least for GHG emissions. However the systems transformation perspective considers impacts that go beyond the atemporal, often very limited purview of much LCA, with its comparisons of like with like — such as Royal Gala apples with Royal Gala apples — at one point in time. It adopts a more dynamic perspective, considering the impacts of food production and consumption systems over time and within a more complex spatial and socio-economic framework.

Thus, from this perspective one asks: how might we consider transport's GHG impacts once the need to recoup investment in

Table 1
Different metrics for assessing the GHG intensity of livestock systems.

	Comments
Quantity based	
kg CO_2 eq/kg product	Favours intensive monogastric production, and feed-based over grass based ruminant systems
kg CO_2 eq/kg protein, iron, calcium, fatty acid profile and so forth	Depends on nutrient: calcium and possibly iron may favour ruminants; grass-fed ruminants may have better Omega 3–6 ratios than cereal fed animals (Aurousseau et al., 2004; Demirel et al., 2006); protein as metric will favour intensive monogastrics. All may also need to be compared with provision of these nutrients by plant based sources.
Kg CO_2 eq/per nutrient density	This is a composite measure of various key nutrients in combination. Balance here is unclear – again needs to be compared against plant based alternatives
kg CO_2 eq/kg food and non food goods provided (leather, wool, feathers, dung, traction)	Variable; on balance likely to favour ruminants in mixed systems
Area based	
kg CO_2 eq per area of land	Emissions lower for extensive systems and for monogastrics
kg CO_2 eq per area of prime arable land required	Emissions lower for extensive systems, both ruminant and monogastric
Resources based	
kg CO_2 eq avoided through use of byproducts or poor quality land to rear livestock; approach quantifies the GHG and land opportunity cost of needing to obtain an equivalent quantity of nutrition from elsewhere	Favours extensive systems and particularly landless household pig and poultry reliant on scraps
kg edible output per specified quantity of ecosystem services provided on farmed land	Depends on which ecosystem services are valued but may favour extensive ruminant systems
kg edible output per given area off the direct farmland eg. on land 'spared' for conservation or biomass production	Favours intensive systems, especially monogastrics
Resilience based	
Adaptability to climate and environmental change	May favour local breeds

Adapted from Garnett (2011). Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy* 36 S23–S32.

supporting infrastructure is taken into account, by increasing the throughflow of commodities and thus their associated impacts? Moreover, transport is seen as inextricably linked with other energy-using aspects of the food supply chain, including refrigeration, packaging, processing and information technology. The transport of most foods inherently depends on refrigeration, while refrigeration makes possible longer supply chains. Thus, the availability of one technology enables heavier use of the other, the consequence being a ratcheting up of energy dependence within the food supply chain.

So far this reassessment of transport is still broadly within the LCA mainstream in so far as it urges the need for adopting a systems expansion approach. LCA methodology has also been advanced through models that consider the marginal impact of changes in consumption on production and land use within other regions, mediated by trade (Kløverpris et al., 2010). However this perspective goes further by considering the porous interface between the technical and human behavioural domains. For example: how do efficiencies in the supply chain increase the supply and affordability of certain foods which ultimately foster new behavioural norms and habits? How does wider provision of the environmentally 'efficient' option (an imported Spanish lettuce, or less GHG-intensive meat) create behavioural 'lock in,' entrenching patterns of consumption that are dependent on this nexus of interdependent, energy using technologies – refrigeration, transport and IT? A sense of movement in time and space is implicit in the analysis, while attention to the effects that technological developments have on human habits, assumptions and practices prompt questions about how the sustainability of different technical approaches might be assessed.

There is perhaps a deeper challenge to LCA within this perspective, which brings in the concept of human agency and moral responsibility. Systems of production, distribution and consumption are viewed in terms of the power relationships between individuals and between countries, of cultural identity and ultimately about what constitutes progress. Instances of this approach can be found in local food initiatives such as the Fife Diet in the UK (Fife Diet, undated) in overtly political 'peasant' movements such as La Via Campesina who call for 'food sovereignty' and who oppose large scale corporations (La Via Campesina, 2011) and among many within the organic movement. While such analyses cast light on the inequities associated with current systems of production and consumption, and their damaging consequences for health and human wellbeing, the corollary assumption – that small-scale, localised production systems are necessarily more sustainable – is nevertheless a value judgment. For example, smallholder adoption of agroforestry practices may or may not halt deforestation, depending on the prevailing socio-economic conditions. These conditions may include the presence or absence of land use rights, labour or forest protection legislation (Schroth et al., 2004). In both systems – large commercial and small-scale subsistence – the governance framework which shapes production and consumption will influence the extent to which undesirable direct and indirect spatial (land use change) and consumption rebound effects ensue. Thus, while emphasis on improving rural livelihoods at one level reflects pragmatic recognition of how millions of people live today, for many within this perspective agrarianism is perhaps seen as synonymous with the good life. Both wellbeing and sustainability are achieved through the harmonious integration of humans with nature through rural living – unlike the perspectives of demand restraint with its potentially misanthropic 'humans out!' approach to wild habitats or of the efficiency perspective with its emphasis on technology to 'spare' space for a separate wilderness while also challenging the very notion of environmental limits.

As regards nutrition, the system transformation perspective, as for demand restraint, sees the nutritional, and environmental challenges as interconnected and to be addressed holistically. 'Food security' is defined to include not just the 'technical' supply of nutrients but also the other key dimensions identified by the Food and Agriculture Organisation, which include accessibility (incorporating affordability), utilisation and stability over time (FAO, 2008). Often an argument is made for local, diverse agricultural systems that produce indigenous crops and animal breeds. These are seen as better able to provide the full range of micronutrients needed for good health than global supply chains which produce and distribute a simplified range of processed, energy- and fat-dense commodities (FAO, 2010a; Toledo and Burlingame, 2006).

Nutritional and agricultural diversity are thus seen as connected, and essential. Fortification and biofortification strategies are judged to represent a second best strategy in that they merely 'top up' inherently inadequate diets and food systems. While they may have a part to play, these techniques must be situated within a broader food-based approach that emphasises greater nutritional and agricultural diversity within the production system (Johns and Eyzaguirre, 2007).

There is clearly a need for studies that consider the implications for GHG emissions, land use, biodiversity and nutrition of different agricultural systems involving various combinations of crops, livestock and innovations such as biofortification. Such an approach would need to go beyond a simple consideration of the GHG emissions associated with different consumption patterns (such as WWF, 2011; Carlsson-Kanyama and González, 2009; Davis et al., 2010) since health and environmental sustainability are explicitly viewed as outcomes of a linked system of production-consumption rather than just of consumption. But even these approaches will be limited since they may not be able to capture the economic value of different production systems and their translation into health outcomes. For example, the nutritional contribution that livestock provide for people in low-income countries is not necessarily a simple relationship along the lines of "more production equals better nutrition." The outcomes are mediated through the impacts of livestock production on household incomes and the knock on effects of income generation on health generally – for example on people's ability to pay for health care or education, both of which have independent positive effects on health. In other words, the system transformation approach recognises that a more complex understanding of health-sustainability linkages is needed (Hawkes and Ruel, 2006). Whether LCA or LCA-type analyses are able to capture and quantify these dynamic interactions, however, is open to question.

3. Discussion

What do we mean by good nutrition? By biodiversity? By limiting climate change? What are our ethical boundaries – livelihoods, labour standards, animal welfare, other species? These questions go far beyond LCA, but LCA researchers need to be mindful that this is the context within which they frame their research.

This paper has broadly characterised three emerging perspectives in the discourse on food system sustainability, and these are briefly summarised in Table 2.

The vision underlying the efficiency perspective is to take current development goals – greater incomes for all, more material consumption, more food – and to use technology to deliver these goals with less environmental impact. At one level it is profoundly pragmatic: it is 'human nature' to want more; the way the world and the market operates cannot or should not radically be changed (past experiments, such as socialism, have failed); the challenge, therefore, is to improve the status quo. This perspective helps drive the development of technologies and practices that achieve greater efficiencies in production and enhance the nutritional qualities of

Table 2
Summary of the three perspectives.

	Efficiency	Demand restraint	System transformation
Focus of attention	Changes in production.	Changes in consumption.	Changes in balance of power among food system actors.
GHG approach	More food for less environmental impact.	Reduce demand for environmentally-impactful foods.	Ill defined: focus on building resilient small-holder systems with (implicit) assumption that environmental sustainability is an outcome of greater equity.
Biodiversity	Increase productivity to 'spare' land for wilderness – "humans out of nature."	Reduce consumption of land-intensive foods to increase land for wilderness – "humans out of nature."	Integrate human agricultural activities harmoniously into natural landscape – "humans part of nature."
Food security	Increase supply of food on global markets	There is enough food to feed everyone if better distributed; emphasis on citizens who consume too much.	Food security not just about supply but multidimensional – includes socio-economic issues of access, affordability, utilisation, stability – emphasis on greater equity of access.
Nutrition	Make status quo healthier: Product reformulations & information; crop biofortification for poor people.	Emphasises chronic diseases of overconsumption & obesity & highlights their associations with animal products.	Greater diversity of indigenous foods; local production for local markets and local consumption.
Values & ideologies	Informed choice; smart consumption; green growth; ultimately 'freedom to consume.'	Greed narrative; limits to growth; ultimately "freedom from consumption."	Fairer terms of trade; capacity building; ultimately "freedom to self determine."
Role of LCA	Highly influential: used to identify hotspots & opportunities for improvement; to compare relative performance of different production systems & techniques; & to highlight 'land sparing' induced GHG benefits of achieving productivity increases.	Highly influential: used to highlight dominant role of livestock in food system GHG impacts; to show lower absolute GHG impacts of plant based diets: & to highlight GHG 'opportunity cost' of using land for livestock rather than carbon sequestration.	Weak role for LCA to date; LCA metrics not yet developed to capture multiple outputs of agricultural systems; or socio economic context within which LCA results need to be situated, nor relationship between technological change & development of new consumption norms.
Challenges & opportunities	How to better understand and quantify rebound effect, including 'leakage' from the food system into other economic areas? What governance framework is needed so that profit considerations do not undermine the land sparing effect?	How to change behaviour? Can an optimal level of meat and dairy consumption be defined? Greater focus on low income & emerging economies needed: what constitutes a culturally acceptable, healthy sustainable diet in these regions?	Interdisciplinary approaches needed to develop methodologies & metrics that capture environmental impacts over time & space & at different scales, as well as socio–technical interactions. Metrics need to include 'outputs' that go beyond food and may be intangible.

foods that are currently marketed and becoming more prevalent. Its strength lies in careful measurement, in identifying where reductions can be achieved, and in highlighting the effects of different production approaches on land use elsewhere. It has also challenged 'common sense' assumptions about the impacts of particular stages in the supply chain, or certain production practices. Fundamentally, however, it fails to engage with the problem of absolute limits. It implicitly assumes that technological developments and the market as it operates today will ultimately be successful in decoupling production (and GDP growth) from negative environmental and health impacts and it accepts, sometimes even endorses, current trends in consumption. These assumptions are open to challenge (Jackson, 2010). It also pays insufficient attention to the porous interface between the technical and the socio-economic domains and the complex relationship between technological developments and behavioural change.

In order to strengthen this perspective, some questions it needs to address include: how can LCA get to grips with assessing sustainability over different temporal and spatial scales? How can it better understand and quantify the rebound effect, including 'leakage' from the food system into other economic areas? If land sparing approaches makes theoretical sense, then what governance framework is needed so that profit considerations do not undermine the land sparing effect?

The demand restraint approach positions consumption as the cause of our environmental crisis. Environmental limits are absolute: rather than 'tinkering at the edges' we need to shrink our footprint by consuming less or reproducing less. While this perspective includes a strong social justice element (contraction and convergence) essentially its vision of the good life is an ascetic one – living better by consuming less. As such it has resonances with much religious thinking, or rather, environmentalism fills the gap that for many, can no longer be filled by religion (Dunlap, 2006).

The value of this approach lies in its questioning of the sufficiency of relative, rather than absolute limits; in highlighting the critical influence of consumption on the overall burden of impacts; and by providing a framework for seeing the connections between problems and addressing them together. Livestock are seen as a convergence issue for a range of interconnected sustainability concerns, to be addressed together (through changing consumption) rather than as stand alone issues. However this perspective can suffer from a lack of nuance around livestock and their positive dietary as well as environmental contributions, perhaps reflecting this perspective's developed world origins and focus. Its overtly moral vision can be off-putting to some who do not share it. Moreover, a robust account of how behaviour might be changed is lacking. This constitutes a priority research challenge. Other critical research questions for this perspective include: is it possible to define a minimum level of meat and dairy consumption such that the micronutrient value of the nutrition package are not outweighed by GHGs resulting from delivery of 'wasted' nutrients (that is, those that are surplus to requirements)? There is also a need for more LCA based assessments of what constitutes a culturally acceptable, healthy sustainable diet in different low income and emerging economies.

The food system transformation approach is perhaps the most political in so far as it sees human behaviours as the outcomes of social structures, rather than just conscious individual decisions. It is the structure that needs to be changed rather than the individual, and this requires understanding of the dynamic interactions among its social, economic and environmental components over time and space. Its rejection of clear demarcations between the environmental, technical and economic domains represent an important challenge to much LCA thinking. Its vision of a good life shares some of the redistributive morality of the demand restraint perspective but it is more optimistic about the role of humans in the natural world – integration between humans and nature is possible and can be achieved, among other things, through a greater focus on social justice. However, some within this perspective may romanticise the small scale and local, failing to subject these systems to critical scrutiny as they do in the case of commercial systems.

Perhaps a central problem with this approach is that, while it is good at identifying the complex nature of the food sustainability challenge, this very complexity presents an obstacle to the development of specific recommendations as to the way forward. To add rigour to this perspective it is worth exploring whether methodologies and metrics can be developed that capture not just environmental impacts over time and space but also the socio-economic consequences of different production approaches, that in turn give rise to environmental impacts – and vice versa. Assessments need also to consider ways of measuring outputs that are not only multiple but not sometimes intangible. There is a need too for approaches that consider the interactions between different components of the system at different scales, and across scales (that is, the relationship between local and global food systems). A few of these questions may be addressed by further developments in social and environmental LCA methodologies but most will require interdisciplinary research, linking LCA and other disciplines.

4. Conclusion

While the three perspectives: efficiency, demand restraint, and food system transformation, have been presented here as separate world views held by different stakeholders, clearly they are not. They are 'tendencies' rather than stand alone ideologies (at least for most people) and individual people or institutions may adopt any one, or all three of these approaches at different times and to different degrees. Each perspective has its strengths as well as its weaknesses and inconsistencies and, perhaps predictably, the reality is that a composite approach to tackling the food sustainability problem, drawing upon all three perspectives, will be needed. However integrating them into a workable way forward requires greater understanding of the values that underlie the individual perspectives and that give rise to differences of opinion among stakeholders.

Values matter, and they cannot be ignored if progress is to be made. Everybody wants 'sustainability' and an end to hunger – but not everyone has the same vision of what the solution – the good life – might look like. The ethical perspectives people bring to the food-sustainability problem influence both their use of the evidence and the solutions they propose – and these often lead to stakeholders arguing at cross-purposes, the result being conflict, or inaction. Greater understanding of what underlies the different approaches to the food sustainability problem can help shed light on why stakeholders disagree, where there are genuine misunderstandings, and where common ground among them may be possible and ways forward agreed. (Hulme, 2009; Garnett and Godfray, 2012).

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