OPEN ACCESS

The 4th World Sustainability Forum
1 - 30 November 2014

http://www.sciforum.net/conference/wsf-4

World Sustainability Forum 2014 – Conference Proceedings Paper

Food Security Challenges: Influences of an Energy/Water/Food Nexus.

Valeria De Laurentiis[1]*, Dexter V.L. Hunt [1] and Christopher D.F. Rogers [1]

[1] Civil Engineering / College of Engineering and Physical Sciences, University of Birmingham, Birmingham, B152TT, UK
E-Mails: huntd@bham.ac.uk (D.V.L.H.); c.d.f.rogers@bham.ac.uk (C.D.F.R.)

*Author to whom correspondence should be addressed; VXD317@bham.ac.uk (V.L.)
Tel.: +44-121-4143544; Fax: +44-121-414-3675.

Received: 1 September 2014 / Accepted: 13 October 2014 / Published:1 November 2014

Abstract: The food/water/energy nexus is the study of the interactions and connections between these three resources, the synergies and tradeoffs that arise from the way they are managed, and the potential areas of conflict. The core of nexus thinking is that no good results can be achieved from considering these resources independently, which means that food security cannot be achieved in a context of either/both water or/and energy insecurity. All three elements have to be assured to foster sustainability, resilience, prosperity and peace. In this paper attention is focused on the challenges posed by this nexus on achieving food security, which is embodied in the first Millennium Development Goal (MDG), which seeks to halve the number of hungry people in the world between 1990 and 2015. The primary aim of the paper is to identify how the nexus mentality underlies most of the pathways that have been proposed to achieve this goal. It argues that significant shortfalls exist and need to be addressed: there is still no generally accepted approach with identifiable metrics for assessing the extent to which a 'food system fosters food security'. Such metrics are necessary when evaluating alternative strategies and negotiating trade-offs therein.

Keywords: Food security**,** Energy/Water/Food nexus

---

1. Introduction

During the World Food Summit (FAO, 1996) food security was defined as a situation ‘when all people at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life’. This definition stressed the importance of elements that go beyond the availability of food which are: access (individual entitlement for obtaining food), food safety and nutritious value, and stability through time.

In the last century the primary focus has been on enhancing food productivity and during the ‘Green Revolution’ (1966-1985) research and technological improvements led to significant increases in yields, which meant that the overall global production kept ahead of the overall demand (Ingram et al., 2013). These increased yields were mainly achieved due to radical improvements in the use of fertilizers, pesticides, agricultural machinery and irrigation systems (therefore greater use of water). However, this was accompanied with higher resource intensity and an increased reliance on oil.

Between 1990 and 2010 the production of food (+56%) grew at a faster rate than the world population (+30%) and yet significant inequalities now exist with regard to access (Defra, 2012, FAO, 2013). For example, whilst in 2008 an estimated 2 billion people worldwide were overweight or obese (Swinburn et al., 2011), in 2011–13 the FAO (2013) estimated that 842 million people suffered chronic undernourishment. In addition this ‘bottom billion’, as they are referred to, had little access to clean water and energy.

Current food production systems that include greenhouse gas intensive food products, in developed and developing countries, continue to deplete natural resources and pollute ecosystems at a rate that is unsustainable and this will compromise the capacity for nations to produce food for future generations. Ultimately in a context of limited resources world exacerbated by the effects of climate change (and associated mitigation and adaptation requirements), the achievement of food security is one of the biggest challenges of the XXI century (Godfray et al., 2010a). This is important when we consider that in future decades it is expected that further pressures will be applied as a consequence of: growing population (expected to reach 9 billion people by 2050), urbanization (urban populations expected to double by 2050), economic growth and consequent changing lifestyles. Each of these will cause an increase in demand for water (estimated to increase by 40%, approximately 1.7 tn m^3, by 2030), energy (estimated to increase by more than 40% by 2030) and land (Defra, 2012, FAO, 2013).

A new approach to food security is required that does not compromise biodiversity and ecosystem services and reduces the impact on climate change (Foresight., 2011), which moves the attention from availability to access, and from calories to nutrients, enriched with a view towards the future (rather than just considering the present needs). Such a radical change to the food system should deliver better nutritional outcomes at less environmental cost, and in order to do so it is necessary to abandon conventional silo thinking by breaking down the barriers between disciplines (Garnett, 2014, Godfray et al., 2010a).

In response to these challenges food security and related research is transitioning to adopt a much broader perspective than food productivity alone (Grote, 2014). This includes improving insights into the interconnectedness between energy, water and food systems (the so-called nexus approach) which underpin future strategic options and pathways with respect to food security.

In this paper, the nexus issues between Energy, Water and Food are firstly defined, and the points of concern (i.e. factor causing pressure on their supply system) are explored. The aim of the nexus approach and potential for achievement of sustainable solutions are then illustrated (Section 2) before highlighting the nexus influences on the food security challenge (Section 3). A concluding discussion is given in Section 4.

2. The Nexus between Energy, Water and Food

2.1 Definition and Historical Context

The word 'nexus' derives from Latin verb *nectere* which means 'to connect', and expresses the study of the interactions and connections between two or more things, often termed dependencies or interdependencies. The water, energy and food nexus is therefore the study of the interactions between these three resources, the synergies and tradeoffs that arise from the way they are managed, and the potential areas of conflict. For example, the basis of food production requires water directly to grow crops, and this water usually requires pumping and treating which requires energy; in turn electricity production is dependent on water for cooling and steam generation. Energy and water are further required for processing, packaging, delivery by industry and ultimately preparation from the end-user.

Figures 1 and 2 show just how closely interconnected the elements of the nexus are. Figure 1 shows the correlation between food and energy prices. This close connection is a consequence of the reliance of modern agriculture on fossil fuels and of first generation bio-fuel expansion, which has made energy and food production become competitors for land and water. Figure 2 displays shares of access to sanitation, energy and food in different regions of the world; as can be seen, generally, water scarcity comes together with food insecurity, which underlines the importance of an integrated approach in order to increase access to all three elements. The origin of all current discussions stems from the realization that the elements forming the nexus are, in their vast majority, limited, necessitating closer study of their intimate relationships and interdependencies, particularly so as resources diminish (Olsson, 2013). This pattern of how the concept of the nexus developed can be identified when searching throughout the literature: the first works mainly acknowledge the risks associated with overexploitation of water/energy/food resources, gradually transitioning to improved identification of connections between them and most recently this has developed into more sophisticated analyses of synergies and tradeoffs. Crucial in this sense was 'The Water Energy and Food Security Nexus, Solutions for a Green Economy' conference held in 2011 in Bonn, Germany, which opened the debate on this vitally important topic matter, a fact emphasised most clearly by the abundance of 'nexus' publications over subsequent years.

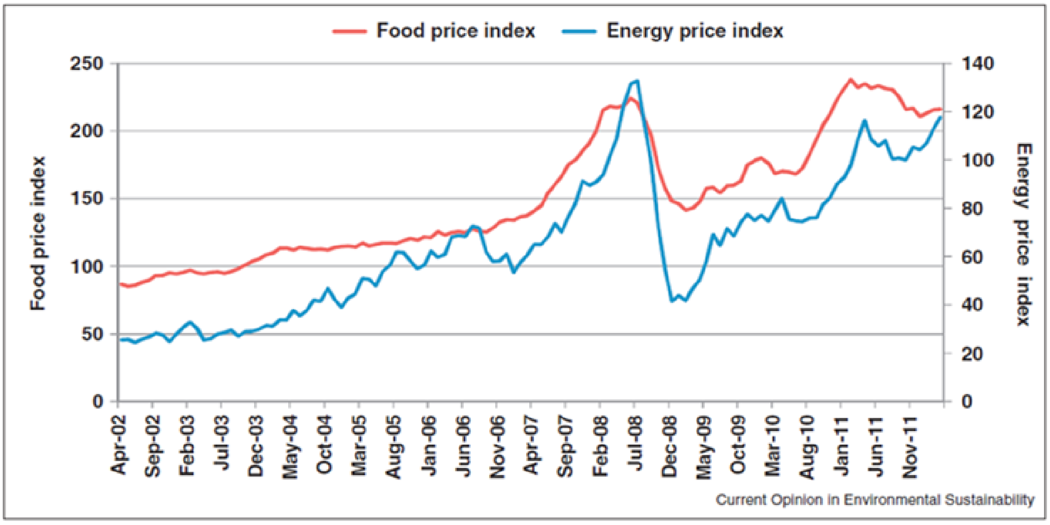

Figure 1. World food and oil prices. April 2002 to March 2012 [Source: (Ringler et al., 2013)]

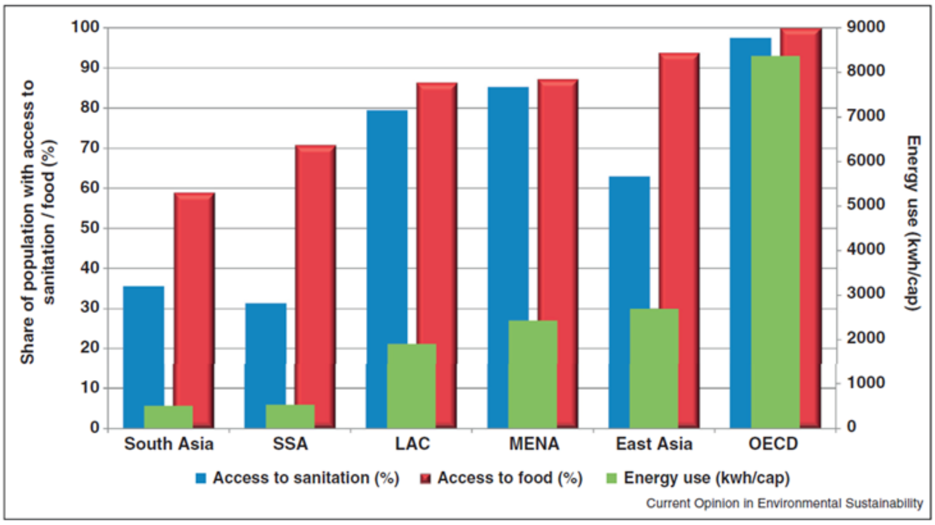

Figure 2. Access to sanitation, food and modern energy systems across regions. SSA: Sub-Saharan Africa; LAC: Latin America and the Caribbean; MENA: Middle East and North Africa; OECD: Organization for Economic Cooperation and Development countries. [Source: (Ringler et al., 2013)]

2.2 Drivers of Pressure on Resources

The main factors that put pressure on the supply of water, energy and food are (Hoff, 2011, Olsson, 2013, Godfray et al., 2010a):

- Urbanization
- Population growth
- Economic development and consequent changing of lifestyles
- Climate change
- Globalization (where externalities of supply are 'hidden')

A combination of economic growth, globalization and urbanization has a negative impact on the earths' natural ecosystem and on resource availability. For example, as people move to more developed cities in general their lifestyles change, in particular by eating more meat and other water and carbon intense products (Figure 3). [Beef cattle has an average water footprint of 15400 m^3/ton, (Mekonnen and Hoekstra, 2010), and a carbon footprint (average value for England, according to the PAS 2050 methodology) of 12.65 kg CO2e/kg (live weight), (APPG, 2013)]. Moreover modern city dwellers have expectations for food to be available all year round (as a consequence of a loss of contact with natural rhythms and seasonality of products). This loss of connection with the natural component of food production, typical of city dwellers, has also caused a stronger tendency to waste food, which implies the waste of water and energy that were involved in the production, processing and distribution requirements (Hoff, 2011, Olsson, 2013). Furthermore the geographical displacement of consumption (from production through farming and home growing) has meant that food waste is no longer used as a resource for animal feed or compost and has become an undesirable output that has to be disposed of in a sustainable manner. In addition climate change, which is contributed to significantly by energy use and food production, is adding further pressures on water supplies and agricultural productivity, as a consequence of rising temperatures, significant changes to normal weather patterns that potentially influence crop yields, rising seawater levels, shrinking glaciers and increase in extreme weather events, like droughts and floods. [Producing and processing food accounts for 14% energy consumption by UK businesses, (DECC, 2014, DEFRA, 2006, 2012), while an analysis from the European Commission (EIPRO, 2006) finds that food accounts for 31% of the total E-25 greenhouse gases emission.] Also in addition climate change mitigation measures can put further stress on key elements of the nexus, for example in the case of water and land intensive practices for carbon sequestration or measures for reducing the carbon emissions such as intensive bio-fuels cultivation (Hoff, 2011).

Global food trade has the (sometimes negative) consequence of giving the opportunity to externalize to other countries resource extraction and waste production, and of generating geo-political tensions when ‘outsourcing’ reliance on other countries for fundamental, crucial resource supply streams. However such an approach has the positive potential for improving resilience of a food supply network/web, through giving a variety of alternative multi-nodal sources to address local scarcities (addressing localised drought or disease issues), and for increasing the overall resource use efficiency, if trade is assumed to follow productivity gradients (Hoff, 2011, Ponomarov and Holcomb, 2009, Wildgoose, 2011). For instance a country that has low availability of water, through choosing to import water-intensive products from another country that has unfettered access to blue (surface and groundwater), green (rainwater) and grey water (polluted freshwater), rather than to desalinate seawater and use it for irrigation, is likely to have a lower water and carbon footprint (Hoekstra and Mekonnen, 2012, IFC, 2013). This means that any comprehensive analysis should include the externalities associated with providing, processing and transporting these resources from elsewhere.

A

B

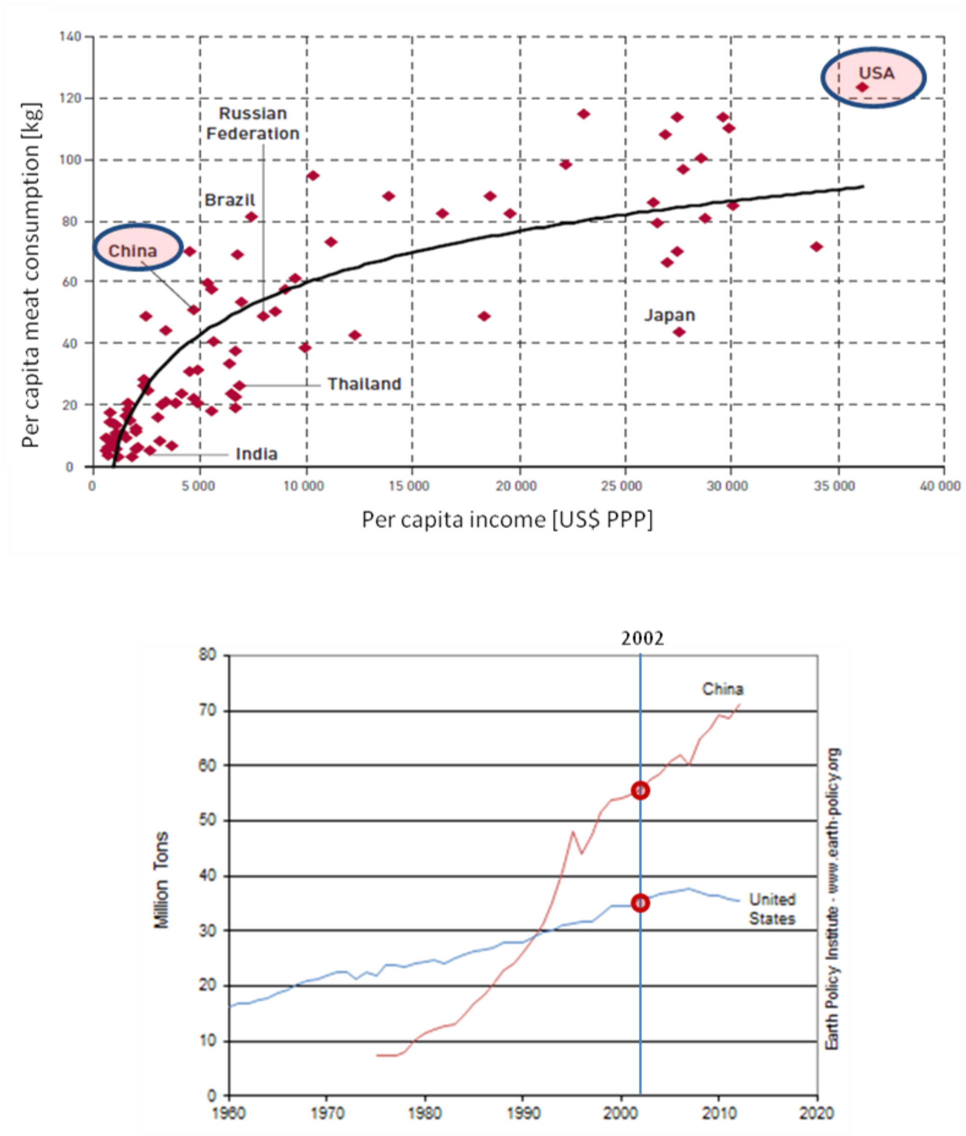

Figure 1. A comparison between per capita and total meat consumption in China and in the USA in 2002. (A) The relationship between meat consumption and per capita income in 2002 [Source: adapted from (FAO, 2006)]. (B) Meat consumption in China and the United States 1960-2020 [Source: adapted from (Earth Policy Institute)]

2.3. The aim of the nexus approach – sustainable solutions

The nexus approach aims to address the pressures on the ecosystems that supply these resources through an integrated perspective, based on the idea that it is not possible to address water, energy or food security alone in an effective way without considering the implications on the other two, in other words the broader consequences caused by the interdependencies between them. The ultimate goal for analyzing the connections between water, energy and food, and highlighting the potential areas for conflict, tradeoffs and synergies, is to guide policy-making towards integrated solutions and approaches to resource use (Bazilian et al., 2011, Hoff, 2011, Howells et al., 2013, Lawford et al., 2013, Ringler et al., 2013). Both the fact that the water, energy and food nexus has been identified as one of the three greatest threats to global economy (World Economic Forum, 2011), and that it has been defined a ‘security’ nexus, as access to all three elements must be ensured in order to have prosperity and peace (Lawford et al., 2013), emphasizes further the importance of achieving this result. The following example shows how a nexus mentality can improve policy guidance toward more integrated 'sustainable' solutions:

EXAMPLE: At the end of the last century India became the largest groundwater user in the world, with an agricultural food growing system that was heavily reliant on groundwater extraction, due to rainwater availability for only 4 months a year - during the monsoon period. This dependence on groundwater was increased further by 'free' subsidized power. However, with inconsistent electricity provision proned to outages, farmers tended to leave the pumps continuously on, causing both high energy and water consumption. The state-government of Guarat introduced innovative strategies to reduce this dependency: through separating the power lines that supplied electricity to villages and irrigation wells, it was possible to introduce a rationing of electricity use for agriculture of eight uninterrupted hours a day and at the same time guaranteeing a constant supply for the other users. This led to the stabilization and recovery of groundwater levels, a decline in electricity consumption, improvement in agricultural production (due to reliability of water supply that motivated farmers to implement new cropping schemes) and improvement in livelihoods of villages and opportunities for growth thanks to the constant electricity supply (Hoff, 2011).

3. Food security and the Nexus between Energy Water and Food

Several challenges can be found throughout literature relating to the concept of food security (Dogliotti et al., 2014, Foresight., 2011, Godfray et al., 2010a). These can be grouped into two main challenges or goals:

- Sustainably balancing the growing demand for food with supply streams
- Ensuring universal access to food, nutritional security and stability through time

Given that both are extremely ambitious and multidisciplinary, this paper focuses mainly on the first goal, as its achievement is a necessary condition for achieving the second and as it has a stronger connection with the nexus.

Numerous pathways have been suggested to reach this primary goal that seek to sustainably manage and mitigate for the contributions that a food system makes to climate change whilst developing food production methods that replenish rather than deplete biodiversity and related ecosystems (Foresight., 2011, Garnett, 2014, Godfray et al., 2010a, Godfray et al., 2010b, Hoff, 2011), the most recurrent of which are:

- Producing more with less and at a lower environmental cost (Section 3.1)
- Changing diets (Section 3.2)
- Reducing waste (Section 3.3)

These pathways are now analysed and their connection with the nexus approach underlined.

3.1. Producing more with less and at a lower environmental cost

There is common agreement (FAO, 2009, Foresight., 2011) that more food will have to be produced at a lower environmental cost and in a resource constrained environment. In terms of water resource availability, in 2000, 10 countries used more than 40% of their water resources for irrigation, and were therefore defined as suffering critical water scarcity (Khan and Hanjra, 2009).

Another resource whose limited availability is critical for increasing agricultural production is phosphorus, which is used in the production of chemical fertilizers (the price of phosphate rock increased by 700% in 14 months between 2007 and 2008) (Cordell et al., 2009). Furthermore chemical fertilizers are highly energy intensive and an excessive use causes water pollution through runoff. There is little space for expansion of land (a key resource) for agriculture, as a consequence of competition over land from other human activities (like urbanization and cultivation of crops for biofuels), and where land is available it may no longer be productive because of unsustainable land management (which lead to desertification, salinization, soil erosion and other consequences) or simply because land banks that must exist for the protection of biodiversity and ecosystems services (such as carbon storage) must be given priority (Godfray et al., 2010a).

The necessity to adopt a nexus approach and develop new, as well as implement existing systems, to optimize the use of inputs in agricultural production is evident. Such approaches include solutions for water conservation (like rainwater harvesting) and efficient water use technologies (on time water delivery and micro irrigation), increased fertilizer use efficiency (through more precise application of fertilizers, nitrogen fixing, use of compost), increased yields to input ratio, reduced carbon intensity of fuel inputs (by using alternative sources for energy production such as wind and solar power or anaerobic digestion) (Garnett, 2011, Godfray et al., 2010a, Ringler et al., 2013). Policies created with a silo approach, which, focusing only on food security, heavily subsidize water and energy for food production, are explicitly in conflict with these initiatives, as a result causing farmers to have less incentive to invest in new technologies (Olsson, 2013).

3.2 Changing diets

About one third of the global cereal production is fed directly to animals (Alexandratos et al., 2006). Even though the efficiency of the conversion of feedstock into animal matter is considerably variable among different species (e.g. the cereal necessary to have a weight increase of one kilogramme is: 8 kg for cattle, 4 kg for pork and 1 kg for chicken), in most cases meat consumption represents a sub-optimal use of land, water and energy resources involved in the agricultural production (Garnett, 2011, Godfray et al., 2010a). In addition, according to the FAO's *Livestock Long Shadow* report (2006) and many other LCA analyses (Baldwin et al., 2010, Gössling et al., 2011, Head et al., 2014, Mogensen et al., 2009), livestock has a strong impact on water pollution, land use and biodiversity, and heavily contributes to greenhouse gases emissions (contributing to 18% of global emissions over its lifecycle).

It has been suggested that part of the solution may be to shift from a meat and dairy intensive diet to a more balanced one rich in grains and other vegetable products that are considered to improve health. In so doing interdependent issues, for example, obesity rates, would likely decrease, thus lowering public health spending on related issues (Godfray et al., 2010a). However an attitude of judging meat rearing and consumption to be always negative is over simplistic, as most of the grass-fed livestock is reared on land which would simply not be suitable for agriculture purposes (e.g. sheep in Scotland). Moreover in developing countries meat represents an important source of some vitamins and minerals which are crucial for children's development (Cooper, 2013, Godfray et al., 2010a).

However, by making explicit the connection between dietary foodstuff and their water and energy input, the nexus approach can support and guide a shift towards less intensive consumption dietary choices, through the development of studies that quantify the energy, carbon and water footprint of food products in addition to their nutritional values. Such an approach facilitates transparently informed consumer choices. As an example an app has been developed by the Dutch organization *Varkens in Nood*, which enables purchasers to scan a product and obtain information on its environmental impact and to receive suggestions for similar products which have a better score (Head et al., 2014). Such innovations are an integral part of a nexus approach.

3.3. Reducing waste

It has been estimated that globally, throughout the food chain between 30 and 40% of food is wasted (Nellemann, 2009). The stages of the food system that experience most waste can vary significantly when going from developing to the developed countries (Figure 5). For example, in developing countries most of the food is wasted at post-harvest stages, as a consequence of lack of infrastructure or storage technologies, whilst in the developed world most of the waste occurs at the retail, food service and household level. There are many reasons for this: low prices of food, which encourage wasteful behaviours; extreme reliance on 'use by' dates, which often underestimate the shelf life of the product for safety reasons; aesthetic criteria for which retailers throw away perfectly edible fruits and vegetables; offers, which encourage consumers to buy more than they can consume; and oversized portions proposed by the food service sector (Godfray et al., 2010a).

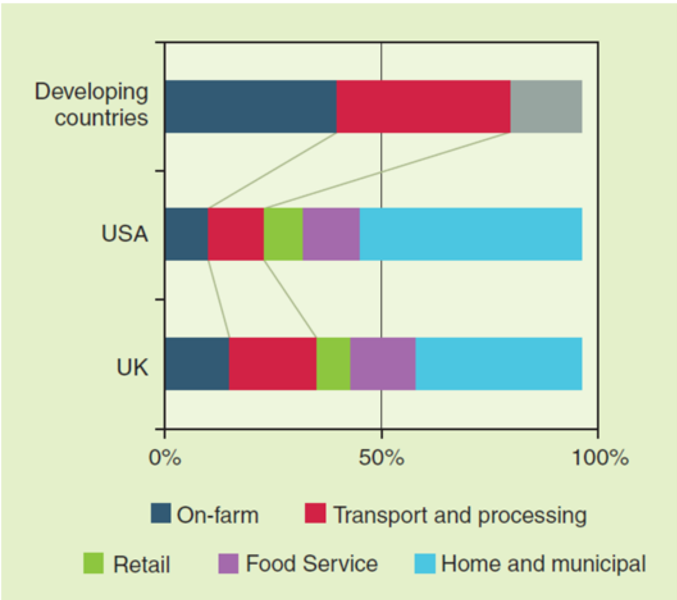

Figure 2. Makeup of total food waste in developed and developing countries. Retail, food service, and home and municipal categories are lumped together for developing countries.
[Source: (Godfray et al., 2010a)]

As with highly energy and water-intensive products, a nexus approach can underline the opportunity for improving overall resource efficiency offered by reducing wastage and losses (in terms of food, energy and water) at all stages within the food chain, and can foster productive recycling of food no longer fit for consumption as animal feed or as a source of energy (Foresight., 2011).

4. Concluding Discussion

In the FAO definition of food security the expression 'at all times' is very significant as it means that uninterrupted access to food has to be ensured today, tomorrow, next week, next year and in following centuries, which embeds the concept of sustainability. However in order for this to happen, even when concomitant shocks or disruptions occur (droughts and extreme weather events for instance), the food system has to be resilient.

The three pathways to tackle food security analysed within this paper: sustainable intensification of agriculture, changing diets and reducing waste, are all ways of making a more efficient use of the resources involved in food system activities and reduce their impact on the environment. A nexus mentality, which involves thinking of resource streams/flows of energy, water, land and food in an interconnected way with the aim of improving the overall efficiency of the overall system, is therefore implicit. A further benefit of the nexus approach is that that it enables tradeoffs between its elements to be foreseen, for example the impacts resulting from the application of a new food related strategy, and therefore it permits prior consideration of tradeoffs when still in the process of development, allowing for refinement or even evaluation of alternative options and/or subsequent management plans.

Being a relatively new subject, the nexus between water, energy and food requires further research to understand how the resilience and sustainability of a food system can be assessed and to what extent a range of alternative food systems would foster food security. This is ongoing research currently being undertaken by the University of Birmingham as part of the Liveable Cities project.

Acknowledgements

This study was funded by EPSRC under the current Liveable Cities programme (grant EP/J017698).

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Alexandratos, N., Bruinsma, J., Bödeker, G., et al. (2006) World agriculture: Towards 2030/2050. Interim report. Prospects for food, nutrition, agriculture and major commodity groups.
2. APPG (2013) The carbon footprint of the beef cattle and sheep sector.
3. Baldwin, C., Wilberforce, N. and Kapur, A. (2010) Restaurant and food service life cycle assessment and development of a sustainability standard. **The International Journal of Life Cycle Assessment**, 16: (1): 40-49.

4. Bazilian, M., Rogner, H., Howells, M., et al. (2011) Considering the energy, water and food nexus: Towards an integrated modelling approach. **Energy Policy**, 39: (12): 7896-7906.
5. Cooper, K. (2013) "The readiness is all: what it takes to feed the city". Birmingham, The New Optimist Forum.
6. Cordell, D., Drangert, J.-O. and White, S. (2009) The story of phosphorus: Global food security and food for thought. **Global Environmental Change**, 19: (2): 292-305.
7. DECC (2014) "Energy Consumption in the UK. Chapter 1: Overall energy consumption in the UK since 1970". Department of Energy and Climate Change.
8. DEFRA (2006) Environmental Impacts of Food Production and Consumption.
9. DEFRA (2012) Food statistics pocketbook. Department for Environment, Food and Rural Affairs.
10. Dogliotti, S., Giller, K.E. and Van Ittersum, M.K. (2014) Achieving global food security whilst reconciling demands on the environment: report of the First International Conference on Global Food Security. **Food Security**, 6: (2): 299-302.
11. EIPRO (2006) "Environmental Impact of Products (EIPRO). Analysis of the life cycle environmental impacts related to the total final consumption of the EU 25". European Commission Technical Report EUR 22284 EN.
12. FAO (1996) "Rome Declaration on World Food Security and World Food Summit Plan of Action". Rome, FAO.
13. FAO (2006) "Livestock's Long Shadow". Rome, Food and Agriculture Organization of the United Nations.
14. FAO (2009) FAO's Director-General on How to Feed the World in 2050. **Population And Development Review**, 35: (4): 837-839.
15. FAO, IFAD and WFP (2013) "The State of Food Insecurity in the World, 2013. The Multiple Dimensions of Food Security". Food and Agriculture Organization of the United Nations Rome, IT.
16. Foresight. (2011) "The Future of Food and Farming". **Final Project Report.** London, The Government Office for Science.
17. Garnett, T. (2011) Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? **Food Policy**, 36: S23-S32.
18. Garnett, T. (2014) Three perspectives on sustainable food security: efficiency, demand restraint, food system transformation. What role for life cycle assessment? **Journal of Cleaner Production**, 73: 10-18.
19. Godfray, H.C., Beddington, J.R., Crute, I.R., et al. (2010a) Food security: the challenge of feeding 9 billion people. **Science**, 327: (5967): 812-818.
20. Godfray, H.C., Crute, I.R., Haddad, L., et al. (2010b) The future of the global food system. **Philos Trans R Soc Lond B Biol Sci**, 365: (1554): 2769-2777.
21. Gössling, S., Garrod, B., Aall, C., et al. (2011) Food management in tourism: Reducing tourism's carbon 'foodprint'. **Tourism Management**, 32: (3): 534-543.
22. Grote, U. (2014) Can we improve global food security? A socio-economic and political perspective. **Food Security**, 6: (2): 187-200.

23. Head, M., Sevenster, M., Odegard, I., et al. (2014) Life cycle impacts of protein-rich foods: creating robust yet extensive life cycle models for use in a consumer app. **Journal of Cleaner Production**, 73: 165-174.
24. Hoekstra, A.Y. and Mekonnen, M.M. (2012) The water footprint of humanity. **Proc Natl Acad Sci U S A**, 109: (9): 3232-3237.
25. Hoff, H. (2011) "Understanding the Nexus. Background Paper for the Bonn2011Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm.".
26. Howells, M., Hermann, S., Welsch, M., et al. (2013) Integrated analysis of climate change, land-use, energy and water strategies. **Nature Climate Change**, 3: (7): 621-626.
27. IFC (2013) "Water footprint assessment". New Delhi. India, International Finance Corporation.
28. Ingram, J.S.I., Wright, H.L., Foster, L., et al. (2013) Priority research questions for the UK food system. **Food Security**, 5: (5): 617-636.
29. Khan, S. and Hanjra, M.A. (2009) Footprints of water and energy inputs in food production - Global perspectives. **Food Policy**, 34: (2): 130-140.
30. Lawford, R., Bogardi, J., Marx, S., et al. (2013) Basin perspectives on the Water-Energy-Food Security Nexus. **Current Opinion in Environmental Sustainability**, 5: (6): 607-616.
31. Mekonnen, M. and Hoekstra, A. (2010) The green, blue and grey water footprint of farm animals and animal products.
32. Mogensen, L., Hermansen, J.E., Halberg, N., et al. (2009) "Life cycle assessment across the food supply chain". In Baldwin, C. (Ed.) **Sustainability in the food industry**. Wiley-Blackwell, Ames.
33. Nellemann, C. (2009) **The Environmental Food Crisis: The Environment's Role in Averting Future Food Crises: a UNEP Rapid Response Assessment**. UNEP/Earthprint.
34. Olsson, G. (2013) Water, energy and food interactions-Challenges and opportunities. **Frontiers of Environmental Science & Engineering**, 7: (5): 787-793.
35. Ponomarov, S.Y. and Holcomb, M.C. (2009) Understanding the concept of supply chain resilience. **The International Journal of Logistics Management**, 20: (1): 124-143.
36. Ringler, C., Bhaduri, A. and Lawford, R. (2013) The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency? **Current Opinion in Environmental Sustainability**, 5: (6): 617-624.
37. Swinburn, B.A., Sacks, G., Hall, K.D., et al. (2011) The global obesity pandemic: shaped by global drivers and local environments. **The Lancet**, 378: (9793): 804-814.
38. Wildgoose, N. (2011) "Avoiding the pitfalls of Supply Chain Disruptions". Zurich.
39. World Economic Forum (2011) "Global Risks 2011". Cologne, World Economic Forum.