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The Sustainability and Security of the Global Food System: The challenges of Peak Oil, Climate Change & Freshwater Depletion

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Introduction

During 2007 and 2008 food security concerns were heightened as a result of a dramatic increase in agricultural commodity prices and the sharp decline in world grain reserves. Indeed, from the beginning of 2003 until the middle of 2008, maize and wheat doubled and rice tripled in price while a range of other agricultural commodities also experienced price hikes (IFPRI 2008). Notwithstanding climate-induced crop losses, most of the drivers of price increase appear to be on the demand side. Von Braun (2007) attributes differently weighted responsibility to a number of drivers of which the two most important are dietary change, especially increased consumption of meat; and the rise in oil prices with its associated push to expand biofuel production.

Yet while high levels of economic growth in Asia, particularly in China and India, have done much to raise household income and strengthen food security over the past decade, the global number of the food insecure has remained stubbornly high. Indeed, according to a recent FAO report, the number of chronically hungry people increased by 75 million in 2007 to reach 923 million (FAO 2008). It is likely that this figure is now close to or has even exceeded one billion people.

In a context where the world produces enough food for all, why has it proven so difficult to reduce the number of hungry and malnourished people in the world? And why, given the undertakings that were made at the 1996 World Food Summit to cut the number of malnourished people (then c.840 million) by half by 2015, does that objective look increasingly unrealistic? Moreover, since that Summit, the number of overweight and obese people has rapidly overtaken the number of hungry with the greatest proportion in developing countries. It is becoming apparent, then, that with increasing numbers of both underfed and overfed people, serious questions need to be asked about the effectiveness of the global food system to deliver sound nutrition. Moreover, new and serious challenges to global food security are making themselves felt beyond simply changing patterns of demand: the prospect of ‘peak oil’ and rising fossil fuel prices; the depletion of freshwater, topsoil and biodiversity resources; and, above all, the effects of climate change.

The purpose of this paper, then, is to explore how intricately intertwined is food security with a range of other pressing global concerns. It will become apparent that increasingly complex, turbulent and unpredictable environmental futures makes the goal of strengthening food security an ever more vital yet challenging prospect. Yet how and when these challenges are addressed, that is the speed and seriousness with which policy makers at a variety of levels formulate truly effective responses, will determine the prospects for achieving not only a more secure, but sustainable, global food system. Ultimately, how we feed ourselves in the years to come may require us to conduct a critical review of the prevailing institutional architecture of the global food system and shift our efforts to building more localised and self-reliant production and distribution networks. This may be the only way that we can reconnect food security with nutritional well-being and environmental sustainability within the resource capabilities of the earth.

The Globalisation of the World Agri-Food System

> “…despite significant scientific and technological achievements in our ability to increase agricultural productivity, we have been less attentive to some of the unintended social and environmental consequences of our achievements. We are now in a good position to reflect on these consequences and to outline various policy options to meet the challenges ahead, perhaps best characterised as the need for food and livelihood security under increasingly constrained environmental conditions…” (International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) Executive Summary p3).

It is apparent that the world agri-food system is becoming increasingly globalised both in relation to the volume and variety of internationally traded food, as well as to the process of dietary convergence (von Braun & Diaz-Bonilla 2008). Yet it is not at all clear that globalisation has strengthened food security, particularly for the poorest, nor is it making the most efficient and sustainable use of natural resources and environmental services. The universal application of the neo-classical model of comparative advantage has strongly encouraged countries to maximise production of their internationally competitive export commodities, using revenues to purchase their food needs through the global market. Yet the evidence strongly indicates that those developing countries engaged in the export of tropical agri-commodities have experienced a significant decline in the terms of trade, that is the relative exchange value of their exports when compared to a typical basket of goods imported from developed countries (comprising food, manufactures, medicines etc). This disparity grew throughout the 1980s and 1990s such that by 2002 the adjusted world market prices of all the major tropical agri-commodities were a fraction of their value in 1980. According to Weiss, the internationally traded price of tea had fallen to 47% of its 1980 value by 2002, groundnuts to 38%, palm oil to 24%, cotton to 21%, cocoa to 19% and coffee to just 14% (Weiss 2007).

For some countries, but by no means many, opportunities have arisen to diversify away from ‘traditional’ agricultural commodities and into new high-value agro-export production. Though guided by the same logic of international comparative advantage as a means to economic development, some countries have taken advantage of new supply chains delivering high-value produce into distant rich country markets. One of the key actors in driving this development, besides wholesale suppliers, are corporate retailers who are exercising, through their buying desks, enormous influence over distant farming systems. For example, Kenya has witnessed considerable expansion of horticultural produce, including green beans and cut flowers; Chile has significantly expanded production of fruits (kiwis, grapes) and farmed salmon; and in South East Asia aquaculture output in the region has increased fourfold since 1990.

Although the lengthening of the supply chains that take fresh produce into distant markets of the rich countries has become an integral feature of this new globalised agri-food system, there are growing concerns about the long-term viability and sustainability of this process. As the IAASTD report states, while acknowledging the scientific and technological achievements that have enabled such improvements in productivity, there are nevertheless grounds for concern in relation to social, economic and environmental consequences. As far as the agricultural sector in developing countries is concerned, this means the diversion of land, water, labour and other resources into production for export rather than for domestic food staples. Moreover, as Roberts (2008) has highlighted, the boom and bust nature of some agri-commodity cycles, arising from a combination of over-supply, higher transport costs and price squeezing by retailers, can result in increased exposure to indebtedness and loss of livelihoods for small farmers and other workers.

A second aspect of globalisation of the food system is the process of dietary change in the developing world that has become known as the nutrition transition. Amongst some of the observed features of this process is the rapid growth in the energy density of foods, an increase in the consumption of edible oils and foods of animal origin, as well as the general sweetening of food supply (Popkin 2005). In other words, across the developing world traditional dietary patterns are being displaced by high calorie, nutrient-poor processed foods. Within the context of increasing urbanization; forms of employment involving less physical exertion; changing patterns of retailing with high levels of market penetration by global supermarket chains; and the influential role of advertising particularly of convenience foods aimed at the young, the effect is to create the conditions for obesogenic environments and a consequent rise in the incidence of obesity and over-weight (Hawkes 2006). Indeed, it has been suggested that the time is ripe in China for increased regulation of food marketing to better align the growing agro-food supply chain there with healthy diets and good nutrition (Hawkes 2007). Such a process might also consider the wider environmental dimensions of the food system.

The food system and fossil fuels

Events in recent years have revealed the degree to which the global food system has come to depend upon cheap energy. In every aspect – from farming, through processing and manufacturing operations to retail and even to the point of consumption – the modern food system rests upon an abundant, low cost supply of energy that is overwhelmingly provided by fossil fuels. For example, just 100 years ago up to half of all farmland in those countries considered to have an advanced agriculture was either in feed crops for the animals required to provide traction for field tasks, or cover crops as part of a rotational system to fix nitrogen. During the past fifty years, however, draft animals have been replaced by diesel-powered machinery and the use of synthetic fertilisers has dramatically changed crop rotations.

With regard to fertiliser, it has been estimated that the annual turnover of nitrogen in the world's crops (that is, the amount taken up and then removed on harvesting food crops) is 175 million tonnes and almost half of this is provided by synthetic nitrogen produced by the Haber-Bosch process using natural gas (Tudge 2003). Indeed, Vaclav Smil has argued that up to half of the present population of the world owes its existence to the availability of synthetic nitrogen for food production and our dependence upon it is truly irreplaceable (Smil 2000). However, the close tie between fertiliser production and energy use - some five per cent of world natural gas production is used as feedstock and process energy for manufacturing urea – ensures that rising energy costs directly impact fertiliser prices. Rising oil and gas prices during 2007-08 resulted in more than a doubling of fertiliser prices within 18 months.

Besides fertilisers, the petro-chemical industry plays a critical role in providing a very wide range of materials for food packaging with a variety of plastics the preferred material for containing food products due to its light weight, versatility, durability, and low cost. It has been estimated that the manufacture of plastics uses around 4% of the world's annual oil production as feedstock with a further 3-4% used to supply the energy during the manufacturing process. However, there are growing concerns about the volume of plastics forming part of post-consumer waste streams with only relatively limited global capacity for their recovery and recycling and very precarious financial margins in undertaking such work. Because most plastics are non-degradable and take a very long time to break down and with more plastics entering the waste stream, particularly as packaging that is disposed soon after purchase, the landfill space required by plastics waste is a growing concern.

However, it is in relation to transportation where fossil fuels, principally oil, make their greatest contribution to the global food system. While it would be difficult to estimate what proportion of the world’s oil supply is used to transport food, it is apparent that the volume used for this purpose has been growing inexorably during the past 50 years. For example, between 1968 and 1998 world food production increased 84% but food trade increased 184% (Jones 2001). Larger volumes of food are being shipped around the world, in part from surplus producing countries to those experiencing a net deficit of demand over domestic production, but also the reverse flow operates. Here, many poorer countries continue to rely upon export earnings from traditional agro-commodities (eg tropical beverages, bananas) while a few are participating in new high-value export horticulture. One of the features of this latter development has been the use of air- freight, which although accounting for only one percent of food-tonne kilometres, produces 11% of the food transport CO2 equivalent emissions, an issue to which we return below.

The term ‘food miles’ (or food kilometres) has come into popular use to describe the distances travelled by foodstuffs from the farm gate to the consumer. Since 1978 the annual amount of food moved in the UK by heavy goods vehicles (HGVs) has increased by 23 percent and the average distance for each trip has increased by over 50 percent. The transportation of food accounts for 30 percent of all road freight measured as tonne-kilometres moved in the UK. Yet even after the provisioning of supermarkets by HGVs from regional distribution centres, food shopping trips by consumers in cars have increased in frequency and length, largely as a consequence of the displacement of local shops by out-of-town retailers (DEFRA 2005).

Were fossil fuels to be in infinite supply there would no reason to suppose that the globalisation of the food system could not continue to rest upon an abundance of cheap energy. Unfortunately, there is a growing body of evidence that indicates that we are at, or close to reaching, a situation of ‘peak oil’ where we have used up approximately half the geological endowment of conventional oil and natural gas. Some of the most salient facts include:

- The biggest oilfields in the world were discovered more than half a century ago on the Arabian peninsula
- The peak of oil discovery was 1965, and apart from the discoveries of the Prudhoe Bay field in Alaska and the North Sea during the 1970s, there has been a relentless fall in discoveries since that time.
- An estimated 80 percent of all oil used in the world comes from fields discovered before 1973.
- Since 1981 we have been using more oil than has been found and the gap between discovery and consumption has been growing wider with every passing year. In 2007 the world consumed six barrels for every one that was discovered (see Figure 1).
- The world is consuming 84 million barrels of oil each day, or 30 billion barrels per year. Even with only a passing acquaintance of geology it is evident that fossil fuels cannot last indefinitely (Leggett 2005)

At one level peak oil reflects the circumstances to which all individual oil fields generally subscribe. That is, when initially tapped and under its own pressure oil flows freely on a rising curve of production until reaching a maximum point, to be followed, as pressure falls, by a declining return until exhaustion. Aggregating the individual bell-curves for each oilfield in the lower 48 states of the USA was a task undertaken by geologist, M. King Hubbert. Plotting the production rates over a one hundred year period to 1956, and using a generous estimate for ultimate recoverable oil, Hubbert calculated that US production would peak in 1971. Although widely ridiculed within the industry peak oil arrived in the lower 48 a year earlier than Hubbert's prediction (Leggett 2005).

Peak oil is not to suggest the imminent disappearance of oil or natural gas but, rather, it recognises that peak flow of these finite natural resources is followed by a long steady decline in production and availability. The problem, of course, is that demand for cheap oil and gas has risen exponentially, as many late-developing countries adopt the industrial growth model that places energy consumption at its core. Given that the oil and gas industry has been systematically pumping from the largest, most accessible reserves, and that the resources yet to be exploited are in the most inhospitable and difficult environments and in smaller fields of lower quality, it is inevitable that oil and gas will become more expensive than hitherto. This raises urgent questions about the viability of many of our patterns of settlement, lifestyles and systems of production including that of food.

In July 2008 the price of a barrel of Brent crude reached an all-time high of $147. Although the price has fallen back significantly in the current financial downturn, observers of the oil industry who subscribe to Hubbert's model believe that with economic recovery, levels of consumption will effectively once again push up against the prevailing ceiling of production that during the next few years will gradually begin to decline. This geological reality explains the recent enthusiasm for biofuels as well as giving a boost to the exploitation of Canadian tar-sands deposits. Although this is not the place to evaluate the relative merits of either resource, it is becoming clear that - at least until the development of third generation biofuels using algae - neither has the potential to be available in sufficient quantities to replace the ubiquity, flexibility and price of oil. Indeed, given our technological and institutional lock-in to oil-based food production, distribution, retailing and consumption it is urgent that more attention is given to preparing the global food system for a future of much higher energy prices.

Climate Change and food

Another truly significant challenge to global food security and sustainability is presented by climate change. There is now scientific consensus around the phenomenon of human-induced climate change with warming of the climate system now regarded as unequivocal (IPCC 2007). While the consequences of climate change for global food security remain uncertain, regional scenarios suggest that there will be markedly different impacts in different parts of the world (Gregory et al. 2005).

For example, in mid to high latitude regions of the world (North America, Russia, Central Asia, Northern Europe) it is thought that the rise in ground-level temperatures will lengthen the growing season and should increase yields at least in the medium term. Increased levels of atmospheric carbon dioxide will also have a generally positive effect on crop growth by enhancing photosynthesis. During the next two decades it may be possible for these regions to grow commercially crops that have not been viable in the past, such as wine grapes and other temperature sensitive fruits, as well as extend the northern limit of cereal cultivation. Yet as warming proceeds there will be increased evapotranspiration and soil moisture losses that will be exacerbated in many regions by a projected fall in precipitation levels. By mid-century excessively high temperatures and water shortages, as well as a likelihood of increased plant disease, fungal infections and pest outbreaks, will threaten crop yields.

For the developing regions of the low latitudes (within the tropics) climate change brings not only warming, which is a concern where crops may already be close to their limits for heat and water stress, but greater variability and more erratic rainfall. Projections of changing precipitation patterns will particularly affect rain-fed agriculture – which covers 96 per cent of all cultivated land in Sub-Saharan Africa, 87 percent in South America and 61 percent in Asia. This will present an enormous challenge in regions where there is already considerable vulnerability, where the majority of households depend most on agriculture and where there are fewer alternative sources of income, and consequently more limited adaptive capacity. With climate change also responsible for changes in the frequency and magnitude of more extreme events – droughts, storms, flooding – it is apparent that in developing regions there is increased risk of significant impacts on food production systems. Potentially, the biggest losers from climate change are likely to be people most exposed to the worst of its impacts and the least able to cope while, cruelly, living in countries that have made the least contribution to anthropogenic warming.

Overall, the food sector is one of the most significant contributors to climate change. One estimate for the entire EU food supply chain suggests that what we eat has more impact on climate change than any other aspect of daily life, accounting for 31 percent of the global warming potential of products consumed within the EU (Tukker & Huppes 2005). The contribution of agriculture alone varies significantly between countries reflecting the mix of different farming systems. In Ireland, with its large dairy and other livestock activities, agriculture accounts for 28 percent of the country's greenhouse gas emissions. However, there are lesser, but significant, emissions at all stages in the food chain including that derived from an estimated 30 percent of purchased food discarded as waste into landfill (WRAP 2007).

Examining the global food system through a lens of sustainability demonstrates, however, the need to take into account a wide range of inter-connected variables. For example, an issue of current debate amongst food policy experts in the UK concerns the increasing volumes of air freighted food with their associated high carbon footprint (Macmillan, et al. 2008). One study has indicated that air freighted fresh Kenyan green beans are 20-26 times more greenhouse gas intensive than seasonally grown UK beans. Yet people have become accustomed to eating beans year-round, while the UK growing season is relatively short. If the season were to be artificially extended in the UK by growing crops under cover with additional heating and lighting, the above ratio begins to shift dramatically. Moreover, the environmental impacts of air-freight cannot be considered in isolation from other social and economic concerns. With Kenya supplying 22 percent of the EU's air-freighted horticultural imports (and South Africa and Ghana both supplying 6%) it has been estimated that 120,000 people are directly employed and a further 1-1.5 million people in Sub-Saharan Africa are dependent upon export horticulture.

In other words, while tackling climate change should be high – arguably at the very top - of the global policy agenda, measures to reduce greenhouse gas emissions that do not take account of the livelihoods of the poor and most vulnerable would be deeply unjust. In this regard, adaptation measures are needed to strengthen the capacity and security of local and regional food systems to supply a greater part of domestic consumption while reducing their dependence on distant markets. Meanwhile, considerably more attention needs to be directed in the rich world toward reducing meat consumption given the significant additional greenhouse gas emissions arising from animal-based food production (Eshel and Martin 2006).

Other environmental challenges: freshwater

As the preceding discussion outlines, energy and climate change represent urgent and complex challenges for the global food system; but they are not the only issues that need attention. As the IAASTD report, as well as the Millennium Ecosystem Assessment (2005) remind us, we need to be more attentive to the social and environmental consequences of agricultural intensification. Amongst the consequences are: the loss of farmland to food production, either through its conversion to urban development or through poor farming practice resulting in increased erosion and loss of topsoil; a deterioration in the stock of biological diversity, both wild species and cultivated genetic variety, with implications for susceptibility to pests and disease; and the unsustainable use of global freshwater resources, an issue suitable for further elaboration here.

Agriculture accounts for around 86 percent of global freshwater consumption, involving the utilisation of rainfall, the diversion of surface water (rivers, lakes) and the pumping of groundwater, including fossil aquifers. Irrigated agriculture provides about 40 percent of global food production from just 18 percent of cropland and accounts for 67% of global freshwater withdrawals (Khan & Hanjra 2008). Yet while there was a five-fold expansion of irrigation systems during the twentieth century, the primacy of hydraulic engineering has gradually come under growing critical attention as the promises of further productivity are set against the displacement of millions of people, the destruction of wetlands and other aquatic ecosystems, problems of waterlogging and salinisation of irrigated soils and the contamination of water sources (Molle et al. 2008). Above all, increasing attention is focussing upon the enormous disparities in access to water, most evident in the levels of extreme poverty and human suffering resulting from the drinking water and sanitation deficit affecting millions of poor people.

One way in which this disparity can be demonstrated is in relation to water footprints. The notion of ecological footprints has become widely used to represent the area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes generated by, a population in a circumscribed area (country, region, city) (Wackernagel and Rees 1996). The water footprint, in contrast, indicates the volume of water required per capita to sustain a population, and it involves adopting the notion of virtual water. In order to assess the water footprint of a nation it is necessary to quantify not only the endogenous water used to produce food for domestic consumption, but also that virtual water which is embodied in exports (which are subtracted from the nation's water footprint) and that virtual 'exogenous' water embodied in imports (which are added to the footprint). Engaging in such an exercise is most revealing, not only of differences in levels of water use between countries, but highlights how prevailing patterns of consumption raise questions of long-term sustainability.

Perhaps unsurprisingly, the USA emerges with the largest water footprint per capita, 2,480m^3/year, with the Mediterranean countries of Southern Europe not far behind. At the other end of the scale the lowest water footprint is represented by China with an average of 700 m^3/year per capita. According to

Hoekstra and Chapagain (2007) the size of the global water footprint is largely determined by the consumption of food and other agricultural products that comprise 86 percent of the total – 73 percent drawn from internal resources and 13 percent from exogenous virtual supplies. The manufacture of industrial products, in contrast, accounts for just 9 percent of the global water footprint, although this varies considerably between rich states (eg the consumption of industrial goods accounts for 32 percent of the total water footprint of the USA) and developing countries (in India this sector accounts for just 2 percent). Domestic water consumption for drinking and sanitation accounts for five percent of the global water footprint

Hoekstra and Chapagain identify four factors that explain high water footprints:

(1) The total volume of material consumption, which is related to gross national income; examples here include the USA, Switzerland, Italy
(2) Climate: in areas of high evaporative demand the water requirement per unit of crop production is relatively large, a situation facing Senegal, Mali, Sudan and Chad amongst others.
(3) Water-inefficient agricultural practices are responsible for a low output per unit of water used; Thailand, Cambodia and Turkmenistan are amongst those guilty here.
(4) Finally, and significantly, a water-intensive pattern of consumption, especially where meat is a major part of the diet. The USA averages meat consumption of 120kgs per capita per year, a level that is three times the global average, but the countries of Western Europe are not so far behind. Given the rapid growth in meat consumption worldwide, it is useful to explore a little more deeply the implications of this dietary change for water use.

It is possible to calculate the virtual water content of all foods, whether of cereal gains - the global average for maize, wheat and husked rice, for example, is 900, 1300 and 3000 m^3 per tonne respectively – to products higher on the value chain. Livestock products have much higher virtual water content than crop products because of their extended production time and the nature of inputs required. For example, beef produced under industrial farming takes, on average, three years to reach the slaughter weight of 200 kg of boneless beef. During this time it consumes nearly 1.3 tonnes of grain, 7.2t of roughages (pasture, silage), 24m^3 of water for drinking and 7m^3 of water for servicing. By calculating the amount of virtual water within the feeds it is possible to estimate the total volume of embodied water in the beef. Although this varies between countries, Hoekstra and Chapagain suggest a global average of 15,500m^3 per tonne, or in terms that we can better grasp: one kg of beef requires around 15m^3 of water to produce. At a time of increasing anxiety about the sustainability of freshwater resources in some regions of the world, such data may require us to ask important questions about the globalisation of diets featuring high levels of meat consumption.

In this regard, water footprint analysis helps to focus upon the productivity of water in agriculture and highlight potential problems in regions with limited water resources that may prove to be practicing inappropriate farming methods under their prevailing endowments of water. It might, for example, encourage some countries to reorient cropping systems away from products requiring a high endogenous water content to those requiring less, with the consequent shortfall in domestic demand for those products met by imports from countries with high positive water budgets and/or greater water productivity. There are two further points to note here.

First, some African countries have hardly any external water footprint simply because they import so little; yet despite experiencing water shortages themselves, they export crops with a high virtual water content, such as horticultural products, cocoa, and cotton. Paradoxically, some European countries (eg UK, Netherlands, Germany) with abundant water resources of their own have high external water footprints (accounting for up to 80 percent of their total) given their imports of agricultural and industrial products. Such a situation reveals that an appreciation for the distribution of water resources worldwide has played no part in shaping the pattern of global trade but ought to be factored into ongoing discussions that are otherwise driven by entirely financial considerations.

A second, and final, observation concerns once again the dilemma of eating beef, and here it is important to distinguish production methods suited to local ecosystem possibilities and those that are designed to maximise output irrespective of the water inputs required. In this regard, one can distinguish between cattle raised on extensively grazed rangelands where pasture is supported by soil moisture and where there may be few alternative possibilities for utilising that land (consider Botswana or Namibia); compared to intensive feedlot production (in the US mid-West) where supplied feeds have been produced under both water and energy intensive systems. It is no wonder that some concerns have been expressed as to the feasibility of producing sufficient animal feed in the next two decades to meet the expected growth in meat consumption worldwide (Keyzer et al. 2005).

A sustainable global food system?

This paper has identified three key areas of vulnerability for the global food system: the depletion of fossil fuel reserves together with rising international demand that will translate directly into higher global food prices; climate change that will likely result in more extreme weather events as well as shifts in regional patterns of rainfall and temperature; and increasing pressure on global freshwater resources exacerbated by dietary changes encouraging greater consumption of meat products.

While acknowledging that considerable achievements have been made in the technological realm of productivity improvements, the global food system remains significantly short of delivering food security for all of the world's inhabitants. Indeed, events during 2007 and 2008 highlighted the extent to which the food system is failing in some parts of the world. The FAO considers that 36 countries are in crisis in terms of food security and require external assistance; 21 of these are in Africa (Evans 2008). Yet the capacity of the international relief agencies, such as the UN World Food Programme and other humanitarian agencies, is barely able to feed 100 million people, perhaps ten percent of those who are hungry. With poor people typically spending between 50-80 percent of their income on food, rising prices have triggered considerable urban unrest in countries stretching from Mexico to the Philippines via Africa and Central Asia. In other words the global food system is confronting a situation of increasing numbers of hungry and food insecure people, with a limited capacity to address emergency needs and with growing political unrest; yet is facing the prospect of increased energy and water shortages and climatic perturbance.

In this context it may seem an appropriate moment to call for a profound and far-reaching review of the rationale that drives the global food system. During the past thirty years, the paradigm of trade liberalisation has dominated all aspects of global economic policy, creating strict rules and agreements that govern international trade, including food and agriculture. Yet although it has helped some countries to speed up their economic performance and create something of a break away group, led by China, in the global race, not only is this group not yet in touch with the most prosperous global leaders but many more countries appear to be running the race heading in the wrong direction. In other words, the rules and institutional architecture that governs this global race of trade liberalisation are deeply flawed and appear not to be designed to protect the interests of many of the competitors.

In light of the issues raised in this paper, it is suggested that the time is now right to critically interrogate many of our earlier growth-centred assumptions within food and agriculture, and begin a process of building a new paradigm in which an ecological approach informs the development of sustainable food systems. Such an approach would rectify the shortcomings of growth-centred productionism, which fails to appreciate that agri-food systems are embedded in complex ecological, economic and social processes and that they are increasingly vulnerable to a host of pressures arising from resource depletion and climatic perturbation. A sustainable food system would need to begin from a process of strengthening local and regional production and distribution systems that sought to safeguard the rights of farmers, communities and nations to effectively determine their own food security and to ensure the conservation of the resources on which they depend.

In developing agro-ecologically appropriate food production systems it is suggested that particular attention must be given to three critical issues:

- The urgent need to avert climate chaos requires significant effort to reduce greenhouse gas emissions from the food chain, which may involve rethinking the role of meat in the globalised diet;
- That all the major actors within the food chain begin a process of strategic withdrawal from hydrocarbons; but reducing consumption of oil and gas should not be compensated by increased use of biofuels derived from food crops;
- That efforts are undertaken to develop a comprehensive audit of global freshwater resources and to redesign agro-food production systems that operate sustainable levels of water withdrawal with appropriate pricing to reflect the scarcity of this resource.

This paper has argued that the global food system is confronted by a stark failure to ensure food security for more than one billion people at present, and is heading into an increasingly complex, turbulent and unpredictable future. There is an enormous challenge to reconnect food security with nutritional well-being and environmental sustainability. Rather than believing the existing institutional architecture can rise to the challenge, it has been argued that we should now embark upon a process of building adaptive, resilient local food systems designed to strengthen regional sufficiency, security and sustainability.

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