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The interconnected challenges for food security from a food regimes perspective: Energy, climate and malconsumption

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A B S T R A C T

Recent experience of food price volatility in global markets encourages closer examination of the dynamics underlying the global food system and reveals a range of contingent factors. Meanwhile a common thread of many recent expert reports has emphasised the need to intensify agricultural production to double food output by 2050. Drawing upon a food regimes approach, the paper argues that the global food system is vulnerable to three inter-connected challenges that make a largely productivist strategy inappropriate. Analysis suggests that there is a strong likelihood of rising energy costs given the anticipated decline in conventional oil supplies which will have repercussions for land-use and food security. Climate change scenarios anticipate rates of warming and drying in large areas of the tropics that will also have huge implications for food security in those areas. Yet the mode of operation of the global food system is to deliver poor quality nutrition with significant dietary health consequences, a phenomenon labelled malconsumption. The paper argues that these issues are closely inter-related and until we address the fact that the global food system remains dominated by powerful economic interests, an effective solution will remain elusive.

1. Introduction

Growing food price volatility during the first decade of the twenty-first century has certainly elicited attention from mainstream science and policy analysis (FAO, 2009; Royal Society, 2009; Science, 2010; UK Government Office for Science, 2011; Economist, 2011). While some documents remain “cautiously optimistic”, that commodity prices will fall from their 2010–11 levels and stabilise as market signals incentivise farmers to produce more food (OECD-FAO, 2011), most are less sanguine about the prospects for feeding the world, especially a global population of 9b by 2050 (Evans, 2009). Indeed, of these recent mainstream reports, there are varying degrees of acknowledgement of the other challenges that intersect with food production – such as projected rates of global warming, freshwater depletion, biodiversity losses, and tightening energy markets – let alone matters of livelihood security and improved access to food for the rural poor. For most, the central solution is to develop and apply new agricultural technologies in order to increase food production. Only one recent report of international significance comes to a different conclusion: the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009), was clear in its advocacy for a new direction in public policy for food and livelihood security under increasingly constrained environmental conditions. As the IAASTD Synthesis Report states: “the current agricultural knowledge, science and technology model requires revision. Business as usual is no longer an option” (IAASTD, 2009: 3).

Yet, developing more sustainable forms of agricultural production that build on the agro-ecological knowledge of small-holder farmers has so far received only limited support from national and international institutions and policies (Pretty et al., 2010; Lang et al., 2009). Not least there remains a hugely powerful status quo that regards the current crisis as requiring the rejuvenation of the existing agri-industrial model. Framing the debate in quasi-Malthusian terms as the need to ‘double’ food production by 2050 to feed a global population of nine billion,[1] the ‘new *productivism*’ is a call for a renewed effort to intensify production (Horlings and Marsden, 2011). It may be that precision agriculture, next generation genetic engineering and nanotechnology (Beddington, 2010; Tester and Langridge, 2010; Gebbers and Adamchuk, 2010; Scrinis and Lyons, 2010) all potentially have a role to play in the future development of the food system; and, as

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[1] Statement made by Jacques Diouf, Director-General of FAO at the high level conference on world food security, Rome, June 2008.

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the Foresight report tells us, should not be excluded *a priori* on ethical or moral grounds (UK Government Office for Science, 2011). Yet some technologies may not be best suited to the needs of many users, nor may they necessarily enhance the human right to adequate food (De Schutter, 2011a). Moreover, the development and extension of property rights and patent laws in combination with genetic technologies has resulted in the concentration of agricultural biotechnologies in a few corporations (Blakeney, 2011) and there remains deep suspicion in many quarters about the use of science for private gain rather than public good, particularly for something as essential as food. Indeed, the privatization and commoditization of the "basic building blocks of life" (Schurman and Munro, 2010) raise profound ethical questions that cannot only be regarded *a posteriori*.

The global food system today comprises a great deal more than the cultivation of primary foods, whether transgenic or organic. As Lang (2010: 88) observes, "power and capital have moved off the land" with the entire relationship between people, food systems and the planet now restructured. This has enabled the major food processing industries, trading companies and supermarket chains – regarded by van der Ploeg as de facto 'food empires' – to exert a 'monopolistic power over the entire food supply chain' (van der Ploeg, 2010, see also 2008). Understandably, this has had a huge bearing on farming systems, as they are reshaped by speculative external forces seeking to exploit specific local circumstances to produce high value goods for distant markets. This inevitably has huge repercussions for ecosystems in which that farming occurs, for farmers and workers, as well as for the quality of the food it produces. It also creates the conditions for greater vulnerability to external shocks, whether climatic perturbation or market prices.

The events of 2007–08 and again more recently are evidence that the global food system is becoming more, not less, vulnerable to external forces. Amongst those that have been identified as being the most significant drivers of food price volatility are: financial speculation; climate change and extreme weather; energy prices and the expansion of the biofuels sector; declining grain stocks; a drastic fall in public investment in agriculture over two decades; and rising consumer demand, both demographic and changing dietary composition. For the World Bank no less than three-quarters of the 140 percent increase in its food prices index from 2002 to 2008 was caused by biofuels and related effects (Evans, 2009). On the other hand, Ghosh (2010) sifts through the evidence implicating higher oil prices and poor weather conditions and makes a strong case for the overwhelmingly destabilising role of speculation on the futures markets for food commodities. Finally, work conducted at the New England Complex Systems Institute not only quantitatively models the dynamic relationship of food prices with financial speculation and ethanol conversion, but traces the links between food price volatility and political instability in North Africa and the Middle East (Lagi et al., 2011a,b).

Such studies not only reveal the complexity of connections between the food supply system and a range of other issues, but demonstrate the need for research that can develop a trans-disciplinary perspective. This approach needs to draw together two divergent challenges. The first is to better understand the sources of vulnerability of the global food system in order to revise thinking about food *security*. Recent experiences of food price volatility demonstrate that the system is highly sensitive to short-term episodic shocks: it lacks resilience and a buffering capacity to cope effectively with such events. This might be partly mitigated by rebuilding global grain stocks and restoring the legitimacy of government interventions to support needy populations. But all the evidence suggests that the global food system as it is currently organized is unlikely to be able to cope with long-term stress arising from climate change. In this regard it becomes a vital task to enhance the adaptive capacity of local and regional food systems (Leach et al., 2010). Yet such measures may constitute little more than band-aids if we do not address the second key research challenge: which is to better understand the fundamental dynamics and locus of control of the global food system. In this regard we require a framework of analysis that can connect agricultural production and food consumption patterns, identify the key vectors of power, and locate them within an evolving economic system that is reshaping people's access to food.

Without seeking to overstate its explanatory capabilities, this paper draws upon the food regimes approach to help highlight some of these issues. While once largely known for its historical periodisation of an emerging international food system, a focus that arguably brought it to a state of impasse (Burch and Lawrence, 2009), it has recently re-emerged as offering a suitable framework to help explain reconfigurations of the global food system (Pritchard, 2009). A food regimes approach offers a wider lens not only through which to examine the structural shortcomings of the existing food order, but it is also alert to alternative models that challenge the ecological and ethical basis of trans-national agri-food supply chains.

This paper has developed as a review exercise, drawing principally upon scholarly articles and documentary sources. A significant amount of material has recently been placed in the public domain concerned with global food security in light of recent price instability (e.g. the UK Foresight Studies; see also *inter alia*: Royal Society, 2009; Science, 2010; EC, 2009; Ambler-Edwards et al., 2009). A striking feature of much, though by no means all, of this work is its preoccupation with feeding a world of nine billion by 2050, with the central axiom the need for scientific and technological innovation in agriculture to raise output. This raises three important considerations. First, it has been argued that population increase and the prospect of hunger assert a powerful ideological claim that overrides questions of distribution or the associated ecological costs of production systems (Feldman and Biggs, 2012). Second, an approach that emphasises agricultural output increasingly regards food, feed and fuels as a set of interchangeable and tradable commodities for international markets rather than constituting the elements for national food security. Indeed, biofuels production designed to enhance energy security in distant countries may well stake a superior claim to land than the cultivation of food staples to alleviate domestic hunger. Third, a concern with food output is not concerned with matters of diet or of *nutritional* security: it assumes the continued global projection of western dietary norms through the process of 'nutrition transition' (Popkin, 2005).

It is in light of these considerations that this paper seeks critically to examine three key areas of vulnerability in the prevailing food system that at once reveals its asymmetrical balance of power. First, the paper will review some of the implications for agriculture emerging from the rising cost of fossil fuels. In the 'peak of the oil age' (Aleklett et al., 2010) biofuels have come to serve as a surrogate source of automotive energy, resulting in the diversion of coarse grains, sugar cane and vegetable oils from food processing into petro-chemical refineries. Indeed, such is the extent to which agri-commodity traders and governments are locked in mutual pursuit of energy security – swathed, it should be said, in the greenwash of 'carbon neutrality' – that it has triggered a host of speculative land deals in the poorest countries (van der Horst and Vermeylen, 2011). Secondly, although it has been recognised that climate change threatens agricultural productivity in the poorest countries (Gregory et al., 2005), recent scenario building exercises reveal just how dramatically warming and drying will exacerbate food insecurity in many regions throughout the tropics. Thirdly, a focus on the global food system rather than simply upon agriculture requires attention to the 'nutrition transition', whereby diets traditionally dominated by regional staples are replaced by highly processed products high in fats, salt and sweeteners. This process is being driven by the worldwide expansion of powerful agri-food corporations that are engaged in the aggressive marketing of branded goods and retail services, particularly within newly emerging markets of the South. Thus, evaluating the extent of food insecurity requires an understanding of the phenomenon of *malconsumption*, together with its attendant dietary health problems.

Each of these three sources of vulnerability reveals the shocking asymmetry that characterises the global food system and the challenges that lie ahead in addressing them. Yet it is not sufficient to make normative statements about the need for new policy responses that recognise the importance of building greater resilience in an era of risk and uncertainty, or of encouraging people to eat more healthily. Rather, it is vital to understand the economic and political processes and structures that give rise to hunger and malconsumption on the one hand with the appropriation, depletion and degradation of ecosystem services and resources on the other. Food regime analysis offers a lens through which to embark upon such a critique.

2. Food regimes and food security

Food regime analysis combines political economy, political ecology and historical analysis to explain how particular relations of food production and consumption are central to the functioning and reproduction of global capitalism (Holt-Giménez and Shattuck, 2011). It is an approach which is less concerned with food as object than with the multiple interconnections and relations to which food commodities give rise including social, cultural and ecological consequences (McMichael, 2009a). Food regimes were once largely known for their historical periodisation of an emerging international food system, with the first (1870–1914) and second (1947–1973) food regimes interspersed with an 'experimental and chaotic era (1914–47)' (Friedmann, 2009). While the period from 1973 to the present has been generally regarded as yet another contested and experimental era, some theorists have argued that this has begun to constitute a 'third' regime with cause to label it as a 'corporate food regime' (McMichael, 2005; Holt-Giménez and Shattuck, 2011; Burch and Lawrence, 2009).[2] Such debates are not of concern here. Rather, the purpose is to utilise a food regimes perspective in order to facilitate a more complex understanding of the shifting locus of power within the global food system. No claims are made as regards the universal and exclusive explanatory capabilities of the food regimes approach: it is simply an extremely useful tool for bringing together diverse perspectives and dynamics (Campbell and Dixon, 2009).

It is as well to remind ourselves that 1973, while marking the end of the second food regime, was the year of the first successful cartel-driven increase in oil prices. This set in motion a lending and debt spiral as banks recycled petro-dollars to non-oil exporting developing countries that led in short order to the Latin American debt crisis of the early 1980s (George, 1992). The political and institutional alignments which then began to take shape at this time (the emerging 'Washington consensus') were best illustrated by the IMF-World Bank Structural Adjustment Programmes imposed on countries of the South (Weiss, 2007). These public policy tools effectively cleared the way for corporate penetration of key economic sectors in the South through privatization of state assets; the dismantling of national agencies such as crop marketing boards and agricultural extension services; and the elimination of social and production supports (subsidies and price guarantees). The establishment of the World Trade Organisation (WTO) and its raft of agreements on trade related measures affecting agriculture effectively "institutionalized the process of agricultural liberalization on a global scale by restricting the rights of sovereign states to regulate food and agriculture" (Holt-Giménez and Shattuck, 2011: 111).

Corporate power is an undeniable feature of the contemporary food system, with private capital moving across borders and throughout the food chain to establish a truly global operation. It is also clear that most of the financial capital that now controls the global food system is no longer located in primary production. For Lang (2010) power now resides with retailers who shape what and how things are grown, processed and sold, with sourcing having shifted from the local and national to the continental and international (see also Vorley, 2003). Others identify the global grain and agri-chemical companies that, in their respective sectors exercise very high degrees of market concentration (Holt-Giménez and Shattuck, 2011; Hendrickson and Heffernan, 2007). While van der Ploeg applies the term 'food empires' to refer to the large processing industries, trading companies, and supermarket chains that "increasingly exert a monopolistic power over the entire food supply chain" (2010: 99).

Under these circumstances it is little wonder that the term 'corporate food regime' has emerged as a label to define a set of rules institutionalising corporate power in the world food system (McMichael, 2009a). It has been argued that this new order is distinct from the second food regime in part due to the 'politics of quality' with the rise in audit processes and neo-liberal governance of transnational agri-food supply chains (Friedmann and McNair, 2008; Friedmann, 2005). Such processes now drive a host of diverse but inter-related developments within the global food system that include: the rise of 'non-traditional' exports of high value fruit, vegetables and fish from the South; the globalised animal protein chains that stretch from the newly planted fields of soybean in the Brazilian *cerrado* to the intensive pork and poultry feeding units around the world; and a supermarket and food service revolution through much of the South that is rapidly transforming consumption patterns. The analytical value of the food regime approach is that it integrates an understanding of food and agriculture within the wider political economy: it locates food within the unfolding of capitalism. Yet it does so while accommodating mid-level analyses across the entire food system (from seeds to consumption practices); understanding the complex dynamics of production and distribution practices with environment (the 'metabolic rift') and by being alert to transnational social movements that challenge the existing order and its unjust practices (McMichael, 2009b; Friedmann, 2009; Campbell and Dixon, 2009; Dixon, 2009).

It seems appropriate, then, to draw upon a food regimes approach through which to view the vulnerability of the global food system and its propensity to further structural failings that are likely to go beyond the experience of food price volatility of 2007–08. Such a perspective makes clear that price fluctuations are more than a matter of disequilibrium between factors of supply and demand. As the system moves inexorably toward the complete commoditization of all factors of production, including all resource inputs, established through a uniform world market price – the ultimate objective of the neoliberal project – this creates the conditions for the complete exchangeability of large agricultural systems in the interests of profitability. van der Ploeg (2010) illustrates this argument with regard to the rise of asparagus farming in Peru. Until the late 1990s asparagus was an unknown crop in Peru but in the past decade it has become the world's largest producer earning US$450 m/year. Unfortunately, the Ica Valley, where 95 percent of asparagus production is located, is also experiencing the fastest rate of aquifer

[2] McMichael (2009a) helpfully traces the evolution of food regime analysis and reviews some of the recent lines of enquiry which this approach has fostered.

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depletion in the world generating huge problems for other producers and domestic water users (Lawrence, 2010). This retailer-driven global supply chain serving Northern consumers – the UK is the third largest importer of fresh Peruvian asparagus, consuming 6.5 million kilos a year – demonstrates the extent of corporate reach (in association with the World Bank which lent the money to develop the scheme) and the mobility of a system which even now is moving its focus of operations toward China "where even 'better' conditions are available" (van der Ploeg, 2010: 101).

If niche production of high-value fresh foods in distant locations for middle-class consumers in Northern markets serves as one expression of this new food regime, then mass production of standardised goods for global markets might well serve as another. Here the capacity of the system to reduce unit costs and drive down food prices in order to bring branded 'Western' goods into the realm of lower-income urban dwellers in the South has transformed consumption patterns in large parts of the world, and here the food service sector might arguably be said to have played the harbinger more than food retail. As Lang et al. (2009) note, the arrival of foreign brands to a developing country can have dramatic effects: creating new expectations, widening choice and 'opening up' consumers to highly processed, energy dense foods. The result is that calorie intakes rise and non-communicable diet related diseases follow.

This *massification* of food production, while it has delivered historically-low prices for dietary energy (providing no account is taken of the multiple externalities), does reveal the rationale of this contemporary phase of the global food system: the engineering (comprising deconstruction, recomposition and combination) of low cost primary materials (including synthetic substitutes) into higher value products which move rapidly and in large volume through the processing, manufacture, distribution and retail branches of the food system. Profitability is contingent upon unit sales: the imperative is throughput. Consequently, every incentive exists for consumers to buy more than they need or can physiologically metabolise: Morgan Spurlock's film *Super Size Me* and the supermarket BOGOF promotion ('buy one get one free') are evidence of this (Sage, 2012). Although this results in excessive amounts of food waste (Parfitt et al., 2010; Stuart, 2009) it might also be argued that the system encourages consumption of cheap food, with significant consequences for personal health and wellbeing. For example, it has been calculated that almost one-fifth of food in the US food system comprises 'luxus consumption', that is food consumed beyond physical need (Blair and Sobal, 2006). A further example of how a food regimes lens helps to better understand the role of food and its essential fungibility as a commodity to serve principally for profit-seeking, is possibly best demonstrated by the conversion of food grains to auto fuel.

3. The inter-locking of food and energy security

In July 2008 the price of a barrel of Brent crude reached an all-time high of $147 and for the first time began to demonstrate how rising levels of oil consumption were effectively pushed hard up against the prevailing ceiling of production. The apparently insatiable demand for fuel to move increasing quantities of food (and other goods as well as people) ever-greater distances now began to have an immediate consequence in food prices. It also, of course, created significant incentives for developing non-conventional sources of oil (e.g. the Canadian tar sands) as well as stimulating biofuels derived from agriculture.

There is no doubt that the global food system such as it is presently constituted has become utterly dependent upon fossil fuels, principally oil and natural gas (Jones, 2001; Pfeiffer, 2006; Sage, 2012). This dependence stretches from the inputs to industrialised agriculture (agro-chemicals and machinery) through food chains that circum-navigate the world and rest upon transport fuels for jet engines, heavy goods vehicles and the family car making the weekly supermarket shop to the manufacture of polymers for packaging. If the widespread substitution of agricultural labour by machinery makes farming everywhere more vulnerable to oil price rises, then reliance upon chemical fertilisers – particularly urea, the source of synthetic nitrogen – reveals the extent to which food and energy have become interlocked. During the twentieth century the world's cultivated area increased by around one-third, though with average yields rising four-fold total output increased by almost six times. "This gain has been due largely to a more than eightyfold increase of external energy inputs, mostly fossil fuels, to crop cultivation" (Smil, 2000:4). However, with up to 90 percent of the cost of urea determined by the price of natural gas, which is used as feedstock and process energy, and with natural gas prices tracking oil fairly precisely, rising energy costs translate directly into higher fertiliser prices.

Between 2005 and 2008 the price of fertiliser increased fivefold, rising at an even sharper rate than the cost of food (Government Office for Science, 2011), which inevitably had a consequence for farmers, especially in the South. Dorward and Poulton (2008) provide a detailed analysis of the complex repercussions of the rising cost of imported fertilisers for maize farmers in Malawi. Here, farm-gate fertiliser prices (excluding subsidy) would be amongst the highest in the world due to the cost of transporting low volumes from the coast into this landlocked country and then into rural areas. Meanwhile many Malawians spend over 25 percent of their income on maize, which is their staple food. Farmers are consequently experiencing a rising break-even price due to the rising cost of fertiliser such that they can barely remain competitive with imported South African maize. Yet government subsidy to make fertiliser purchase more affordable and boost domestic production represents a huge drain on the national budget - in the order of 17 percent of the 2007–08 budget according to Dorward and Poulton (2008). Rising energy prices consequently translate directly into domestic food production capacity and ultimately into the food and nutritional security of farmers and low-income urban dwellers.

There is growing recognition that conventional oil, that is the light crude which has dominated production to date, is close to or may have already passed peak supply (Murray and King, 2012; Hirsch, 2007). This represents the point of maximum output, with aggregate global production amounting to nearly 85 million barrels per day (Aleklett et al., 2010). Even the IMF's recent World Economic Outlook notes that the "persistent increase in oil prices over the past decade suggests that global oil markets have entered a period of increased scarcity" and that a return to abundance is unlikely in the near term (IMF, 2011: 89). Although there may yet still be, even by conservative estimates, another one trillion barrels of conventional oil that could be exploited, it is as well to remember that since 1981 we have been using more oil than has been found and the gap between discovery and consumption has been growing with every passing year (Campbell, 2003). In 2007 the world consumed six barrels for every one that was discovered. Moreover, many of the remaining known reserves are generally located in smaller fields that are more costly to exploit; these new fields are increasingly likely to be found offshore where the engineering challenges (and the environmental risks) are very much greater. For example, the recently discovered Tupi field off the coast of Brazil not only lies below 2 km of ocean but a further 4 km below the seabed within a salt field that presents additional complications. The difficulties of recovering conventional oil from such deposits has made the development of non-conventional sources more attractive and cost competitive. One such development has centred upon tar sands in the Province of Alberta, Canada, which involves

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large-scale open-cast mining of bitumen and considerable processing to turn this into useable crude oil. The ecological costs of this industry are considerable and have been the subject of widespread criticism (Environmental Integrity Project, 2008; Polaris Institute, 2010). Yet even under full production output is only expected to reach 4.7 m barrels/day by 2035 which will hardly make up the difference in the rate of decline of conventional oil (Murray and King, 2012). It is little wonder that, when the net energy returns on such developments are so evidently marginal, the search for substitutability has fastened upon biofuels as an ideal alternative to liquid petroleum (Dodson et al., 2010).

The development of energy sources from biomass, particularly agricultural crops such as sugar cane, maize and oil palm – hence McMichael's preference for the term agrofuels to refer to crops that compete for land (McMichael, 2009b) – has further cemented the interlocking of energy and food security. It can be expected that ethanol output will continue to rise sharply given the 30 percent increase in prices during 2010 (OECD-FAO, 2011). Although there are efforts underway to develop so-called 'second generation' cellulosic biofuels and even third generation using algae (Murphy, 2010), the short to medium term looks set to remain dominated by sugar cane and maize (ethanol) and palm and other vegetable oils (biodiesel). This will be reinforced by statutory targets such as the EU's Renewable Energy Directive that requires total transport fuel to comprise 10 percent from renewable sources by 2020. Similar targets have been set in the USA and other highly developed and newly emerging economies, primarily as a way of off-setting vulnerability to rising oil prices, but discursively much is also made of the reduction in greenhouse gas emissions (Buyx and Tait, 2011; van der Horst and Vermeylen, 2011).

Overall, there is little doubt that agro-biofuels will continue to significantly impact upon food security, particularly as powerful emerging economies scramble to take control of land in some of the poorest countries in pursuit of their own food and energy security. Some of the largest land leasing and investment proposals have featured a high element of biofuels production, for example the attempt by Daewoo, the Korean conglomerate, to lease 1.3 m ha in Madagascar (representing 40 percent of its arable land) for biofuel and food. The proposal triggered such protests that the government of Madagascar fell from office and the incoming president cancelled the deal (Cotula et al., 2011). China has apparently acquired 2.8 m ha of land in the Democratic Republic of Congo for a biofuel oil palm plantation (von Braun and Meinzen-Dick, 2009), yet this in a country where 76 percent of the population is regarded as undernourished (Robertson and Pinstrup-Andersen, 2010). Other land deals have been struck by Saudi Arabia, other Gulf States, South Korea and China in Sudan, Ethiopia, and Mozambique amongst other African states; and with Cambodia, Laos, and the Philippines and other poor Asian countries.

It is clear that food price volatility has revealed the extent to which food and energy markets have become interlocked, with 'peak oil' triggering multiple and far-reaching repercussions for the global food system. A food regimes framework demonstrates how the food needs of the poor can be subordinated to the energy demands of the more powerful and, by recognising the essential fungibility of agri-commodities, is better able to explain the rise of biofuels within the wider global political economy. That this process is framed by a discourse that positions biofuels as a 'green' response to the dilemma of rising oil prices is, of course, the ultimate incongruity.

4. Climate change and food security

It is now generally regarded as unequivocal that rising atmospheric concentrations of carbon dioxide and other greenhouse gases that derive from human activities, including food production, are having a discernible influence on the world's climate (IPCC, 2007). Ongoing regional scenario-building exercises using general circulation and statistical crop models suggest that there will be a growing divergence between major world regions in terms of agricultural output, and this will also alter their relative 'comparative advantages' having a major effect on trade flows. It is believed that the mid- to high-latitude regions of the world will benefit from a rise in ground level temperatures that will lengthen the growing season, and increased atmospheric concentrations of CO_2 will have an additional fertilisation effect such that rain-fed wheat yields in Northern Europe might increase by as much as 30 percent (Keane et al., 2009; IPCC, 2007). Regions throughout the tropics, on the other hand, are likely to experience a significant deterioration in cereal yields in the decades ahead, with countries such as Malawi needing to adapt to a possible 20 percent reduction in agricultural export earnings because of reduced agricultural output as a result of climate change (Keane et al., 2009).

The main impacts of climate on agricultural production can be identified as will arise from the effects of, and interactions between, the following:

- Higher temperatures putting greater heat stress on crops, animals and farmers.
- Changing precipitation patterns that will disrupt established cycles of rain-fed agriculture and associated livelihood activities;
- The likely development of new pests and disease that will not only affect crops and animals but worsen the existing burden of human ill-health;
- Increased likelihood of extreme weather events (drought, floods) that not only directly impact agricultural production but destroy physical infrastructure affecting distribution.

In practice impacts are likely to be exacerbated by the dynamic interactions between these individual variables. For example, drought and heat stress are tightly coupled as rising temperatures result in increased rates of evapotranspiration which may not be met by available soil moisture provided by seasonal rainfall or irrigation. Battisti and Naylor (2009) highlight the likely consequences of higher temperatures for an already food insecure region such as the Sahel. Crop and livestock production play an essential role in the region's economy, employing around 60 percent of the active population. The region experienced prolonged drought (from the late 1960s to the early 1990s) which resulted in countless hunger-related deaths, unprecedented rates of migration, and the impoverishment of hundreds of thousands of households that lost their livestock and other assets. Yet despite rains returning to some parts of the Sahel over the past 15 years, maize, millet and sorghum yields remain low; and there is limited access to improved varieties, fertilisers, credit or irrigation. Moreover, growing season temperatures are not only very high (ranging from 25 C in the south to 35 C in the north) but are trending upward such that, by the end of this century – and earlier for some parts of the region – they will exceed the hottest seasons recorded during the past century. "Such heat will compound food insecurity caused by variable rainfall in the region", argue Battisti and Naylor, with heat stress making "the region's population far more vulnerable to poverty and hunger-related deaths and will likely drive many people out of agriculture altogether, thus expanding migrant and refugee populations" (2009: 243).

Mapping the effects of climate change on food insecurity throughout the tropics is work currently being undertaken by a CGIAR programme. Looking to identify 'hotspot' locations of food insecurity arising from climate change required the application of

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a number of more sensitive indicators than average season growing temperatures. Using predictive data of temperature and precipitation up to 2050 from a number of global climate models, a series of derived indicators were developed and applied to a broad belt of the Earth between 35 degrees South and 45 degrees North. Some of the key conclusions include:

- The length of growing period flips to less than 120 days in a number of locations across the tropics including Mexico, northeast Brazil, Southern and West Africa and India. This is a critical threshold for a number of crops as well as rangeland vegetation.
- Reliable crop growing days decrease to critical levels below which cropping might become too risky to pursue as a major livelihood strategy in a large number of places across the global tropics, including West Africa, East Africa, and the Indo-Gangetic Plains.
- High temperature stress (above 30 °C) will be widespread in East and Southern Africa, north and south India, Southeast Asia, northern Latin America and Central America.
- Changes in rainfall quantity and quality which are likely to make rainfed agriculture riskier in many parts of the tropics. Such changes include: increased variability in timing; reduced rainfall per rain event; and increased rainfall intensity leading to increased runoff and erosion (Ericksen et al., 2011).

Ultimately, this work must combine these threshold indicators with an understanding of the contemporary food security status of regions to begin to map their vulnerability to climate change. For as Devereux and Edwards (2004: 24) note: "if the households and countries that stand to lose food production due to climate change are also those that depend most on agriculture and have fewest alternative sources of income, then falling harvests will certainly undermine household and national food security". In other words, the biggest losers from climate change are likely to be people who will be most exposed to the worst of its impacts and are the least able to cope. In which case we must ask: how will the global food system respond to the increasing vulnerability of millions of poor people?

Although food security is about access to food and not determined solely by self-sufficient production, it is unlikely that sufficient food could be imported from temperate zone countries regarded as potential medium-term beneficiaries from global warming to balance the food deficit of the tropics. This is because the expected decline in agricultural GDP and in purchasing power, coupled with the continuing rise in global food prices, will simply make commercial purchases of cereals on world markets unaffordable for many of the poorest countries (Hoffman, 2011). Moreover, it is difficult to imagine how food aid can grow to fill this gap: currently the UN World Food programme struggles to feed fewer than 10 percent of the world's malnourished. In this regard, food security needs to be understood, not as an inevitable and immutable outcome of biophysical changes in climate, but as a reflection of social, economic, institutional and technological responses (and non-responses). It is, above all, about grappling with an entire nexus of inter-related issues concerning hunger, poverty, social and economic inequalities, health and nutrition, climate change and resource depletion. Approaching these issues collectively quickly reveals that *productivist*, high external-input agriculture producing for distant markets is less likely to resolve the essential vulnerability of food insecure populations. Rather, it is about designing food production capabilities that enhance resilience, can foster adaptation to changing circumstances and contribute to mitigation.

In their ground-breaking report (De Schutter, 2009), the IAASTD (2009) usefully distinguishes between two kinds of adaptation: autonomous and planned. Autonomous adaptations are triggered by ecological, economic or welfare changes and involves the implementation of existing knowledge and technology in response. They are therefore largely an extension of existing risk-management activities and include changes to cropping patterns (using new crop species or varieties), water management practices and perhaps the diversification of agricultural and household activities. Planned adaptations, in contrast, represent a more deliberate set of decisions that recognises that change is underway and action is required to maintain or achieve a desired state. Such a response may be about increasing adaptive capacity, perhaps by investment in critical infrastructure or by the development of new knowledge and management practices tailored to anticipated changes in climate. A concerted effort at international level to challenge the productivist model of agriculture and to build support for a multi-functional model of sustainable intensification is a vital first step in planned adaptation. Working with national governments and regional bodies to develop agri-food systems that are more resilient, equitable and sustainable; that deliver outputs that contribute to local food security and which create synergies with other policy domains (health, nutrition, employment) offers a genuine alternative to a neo-liberal agricultural model failing to feed the global population in a warming world.

Ultimately, however, the extent of the challenge presented by climate change for food security will largely rest upon the ability of the global community to engage in a collective emissions reduction strategy that will ensure that we keep to a minimum any breach of the 2 degree increase threshold in global mean temperatures that might trigger mega-catastrophes (Kousky et al., 2009). In this respect given the contribution of food supply to greenhouse gas emissions particularly in the wealthiest parts of the world – for example a European study found that food accounts for 31 percent of the global warming potential of all goods and services in the EU-25 (Tukker et al., 2006) – then efforts to reduce these impacts would appear essential. This means that we must address not only how we produce and distribute our food, but also what it is we eat (Garnett, 2011). Making changes in patterns of consumption might also improve health and wellbeing in many diverse populations.

5. The nutrition transition and malconsumption

Throughout the 1970s and 1980s food security was principally concerned with basic foodstuffs, such as cereals and tubers, to resolve problems of protein-energy malnutrition. This began to change by the late 1980s when health and nutrition research findings, first, began to demonstrate the role of disease in preventing the effective utilisation of food; and, secondly, highlighted the significance of micro-nutrient deficiencies in poor health. Today, although one billion people remain malnourished with insufficient protein and energy intake to sustain a healthy active life, a larger number experience a different form of *malconsumption*, resulting in excess intake of calories that contribute to overweight and obesity. Indeed, the paradox of this phenomenon of obesity is that it is becoming much less a feature of the wealthy who can afford to indulge in over-consumption but more a burden of the poor across the world.

Changing patterns of body composition largely reflects changing diets with energy-dense, nutrient-poor 'pseudo foods' (Winson, 2004), comprising high levels of vegetables oils, animal fats, sugar and salt, becoming a ubiquitous feature of the global food system. The prevalence of diets characterised by such foods has been labelled the 'nutrition transition' (Popkin, 2005), a process whereby long-established dietary patterns and culinary traditions

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dominated by regional staples (grains or tubers) are replaced by 'Western'-style highly processed products (Pingali, 2006). This shift from starchy staples to more fatty foods as people's incomes rise is known as Bennett's Law (Godfray et al., 2010). There are a number of factors underpinning this change particularly within the newly emerging economies of the South: increased urbanisation; increased household income; greater market penetration by foreign brands, global supermarket and food service chains; the expansion of advertising and mass media; and highly competitive prices.

Although there is an emerging critical geography of corpulence that rejects the discursive construction and scientific legitimation of the 'obesity epidemic' (Colls and Evans, 2009; Guthman, 2009), this does not detract from recognising the ways spatial injustice is reflected in access to food and health. Nor does it challenge the causal evidence that links obesity with adult-onset diabetes that is directly responsible for a host of health problems including heart disease, kidney failure and the loss of eyesight and limbs. Today the country with the largest number of diabetic patients is India (Popkin, 2010).

Such developments demonstrate the contemporary dialectics of poverty which result from the control of the global food system by powerful corporate interests. Adopting a food regimes approach themselves, Campbell and Dixon (2009) remind us that underpinning the ordering and re-ordering of the global food economy is the essential fact that populations sell their labour power for food. As commoditization and neo-liberalism proceed, bringing all into the ambit of the global marketplace judged by the principle of comparative advantage, it is hardly surprising that an increasing proportion of rural dwellers are net purchasers of food. And where small farmer agriculture is continuously undercut by low price imported staples produced under greater economies of scale elsewhere (and often supported by a raft of hidden subsidies), then re-orienting production to export markets becomes one of the last remaining acts of survival before ecological and economic pressures overwhelm. Hence, the rise of high-value food exports from South to North while consumption is met by low price energy dense processed foods. This food regimes perspective consequently reveals how achieving food security, once largely considered a responsibility of nation-states on behalf of its citizens, is replaced by acceptance that this is now a service performed by transnational agri-food corporations on behalf of consumers – urban and rural, in the South and North – worldwide.

In a highly revealing paper Hawkes (2006) illustrates how globalisation and trade liberalisation, involving investments by transnational food corporations into countries of the South, have transformed dietary patterns. She does so by underlining the context dependence of global processes so that there might be many different outcomes for people whether urban or rural, the poor compared to the rich, and their relative risk from under-nutrition or over-nutrition. In this regard she distinguishes between 'dietary convergence' and 'dietary adaptation', with both part and parcel of the nutrition transition. Evidence suggests that as countries become more integrated into the world economy dietary patterns converge with "increased consumption of meat and meat products, dairy products, edible oil, salt and sugar, and a lower intake of dietary fibre" (p.3). Dietary adaptation, on the other hand, is "increased consumption of brand-name processed and store-bought food, an increased number of meals eaten outside the home and consumer behaviours driven by the appeal of new foods", reflecting increased exposure to advertising and the emergence of new food retail outlets (Hawkes, 2006: 3). Although Hawkes demonstrates that these two dynamic and competitive forces of convergence and adaptation create more complex outcomes than often represented by the 'Coca-Colonization' hypothesis, these dietary transitions are, nevertheless, associated with

> "rising rates of overweight, obesity and diet-related chronic diseases, like heart disease, diabetes and some cancers. More people now die of heart disease in developing countries than in developed, and the problem is becoming more serious among the poor. Low quality diets are also associated with undernutrition in the form of micronutrient deficiency, which, in turn, lowers immunity to infectious diseases. Poor diet quality is thus associated with a dual burden of malnutrition and disease" (Hawkes, 2006: 2).

Hawkes goes on to illustrate how foreign direct investment in the manufacture and retail of processed foods is changing consumption patterns in a country such as Mexico. Mexico is indeed an excellent example of how agri-food corporations can transform an entire society once political agreements have removed any obstacles to their free operation. Patel (2007) notes the significance of the North American Free Trade Agreement signed in 1994 and the impact this was always likely to have on Mexico's maize (corn) market as cheap US imports undercut *campesino* production. Yet while maize prices fell 50 percent between 1990 and 2003, tortilla prices tripled during the 1990s and doubled again during 2006, so that those on low incomes were forced into less-nutritious alternatives such as white bread and noodles (McMichael, 2009b). Tortilla prices, it should be noted, have been significantly affected by the high level of market concentration enjoyed by the major grain traders (such as ADM and Cargill) that also have strong interests in biofuels and meat production. As increasing amounts of yellow maize were diverted to ethanol distilleries, the supply of white maize – regarded by Mexicans as superior for its eating properties – was removed from the tortilla chain to provide the substitute cattle feed (Holt-Giménez and Patel, 2009).

Yet while this traditional food staple was becoming ever more expensive, sales of processed foods have grown quickly with particularly rapid expansion in the snack food, baked goods, dairy products and soft drink categories. For example, consumption of Coca-Cola drinks rose from 275 servings per person per year in 1992 to 487 in 2002 (a level greater than in the United States). Even in rural areas, according to Hawkes, "it is typical for children to buy soft drinks and snacks everyday in school breaks. Higher consumption of these energy-dense foods …has been linked with obesity and diet-related chronic diseases" (Hawkes, 2006: 7/18). Indeed, a recently published on-line report by the United Nations Special Rapporteur on the Right to Food, Oliver De Schutter, reveals just how seriously the Mexican dietary health situation has become. The report notes that:

- With regard to food insecurity progress has been uneven and deprivation levels in enjoyment of the right to food remain dramatic for a large part of the population. Some 19.5 m people lived in food poverty in 2008, up from 14.4 m in 2006.
- The "state of emergency" that Mexico is facing with regard to overweight and obesity. It notes: "35 m adults – 7 out of 10 – are overweight or obese: these people will experience sickness, on average, for 18.5 years during their lifetime. Overweight and obesity are increasing at all income levels, although fastest within the lowest quintile…" It has been calculated that type II diabetes, cancer and cardiovascular diseases cost Mexico 67 billion pesos (US$4.9 billion) in medical care and in premature deaths in 2008, and by 2017 these direct costs will rise to 78 billion pesos (US$5.6 billion).
- Although a National Agreement for Nutritional Health was reached in January 2010 it remains a blunt tool for changing

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> consumer behaviour. As a result, "for many Mexicans, particularly in urban areas or in the northern states, switching to healthier diets is becoming increasingly difficult. The trade policies currently in place favour an increased reliance on heavily processed and refined foods, with a long shelf life, which does not favour the consumption of fresh and more perishable foods, particularly fruits and vegetables" (De Schutter, 2011b).

This account of the deteriorating nutritional status of the Mexican people is occurring, it should be noted, in a country that possesses a distinctive and internationally regarded food culture and culinary tradition, as well as providing the world's genetic reservoir for maize. It demonstrates why it is necessary to reformulate prevailing conceptions of food security in order to permit a theoretically-grounded framework capable of accommodating multiple levels of analysis. A food regimes approach has the capability of doing this, linking material transformations such as distortions in dietary practices that compromise health and well-being to changing transnational trade rules that serve to facilitate corporate penetration of domestic markets. In short, food regimes analysis locates the nutrition transition – and *malconsumption* – within an understanding of power relations (Dixon, 2009).

6. Conclusions

This paper has highlighted three dimensions of vulnerability confronting the global food system: the interlocking of food and energy markets, the threat of climate change and the problem of malconsumption arising from the nutrition transition. Energy security and climate change have been labelled the 'yin and yang' of high energy society: scarcity and abundance that are connected through a shared relationship to a carbon-intensive mode of existence (Bridge, 2010). Moreover, both share characteristics of post-normal science, where facts are uncertain, stakes are high and decisions urgent (Friedrichs, 2011). Arguably, their point of intersection is most acute in relation to the changing dynamics of the global food system, which itself encapsulates this carbon intensity, and it is certain they will act singly and in tandem to cause further volatility in food prices.

The third element, changing consumption practices – primarily although, of course, not confined to – the South highlighted how the nutrition transition is affecting dietary health. However, it is also linked to climate change given that it invariably includes increased consumption of meat products which have higher greenhouse gas intensity than do other food products (Garnett, 2009).

In this regard Lang (2010) is correct to call for a new era of food policies that build upon recognised environmental limits (the 'New Fundamentals') to deliver low carbon, nutritious and sustainable food. This will require a thorough revision of understandings of food security that go beyond the conventional framing of access, availability and affordability, to include an expanded appreciation factoring in all diet-related ill health, not just hunger. Other desirable aspirations for food and agricultural policy include finding ways of meshing embedded carbon, water and land use into common standards by which to judge food, rather than using the price signal alone; and this, in turn, will require significant effort to recalibrate consumer aspirations engaging them in lowering food's impact on the environment (Lang, 2010). Yet, while we need policy measures at all levels – from local to global – that work synergistically to feed everyone – sustainably, equitably and healthily – the food system remains dominated by powerful economic interests that the institutions of global public policy seem unwilling or unable to regulate (see Hawkes and Buse, 2011).

In this regard, the food regimes approach has a useful role to play in demonstrating that the pursuit of neoliberalism in food and agriculture worldwide over the past thirty years – irrespective of whether it constitutes a third regime – has left a terrible legacy of environmental damage, resource depletion, one billion undernourished and more than one billion over-nourished and overweight. For this reason, we need further research that is less preoccupied with the development of new technologies to feed nine billion people in 2050, but more concerned with revealing the interconnections between a hegemonic agri-food system, the degradation of environmental support systems and stressed human metabolic states. Only then will we be able to devise effective global governance capable of resolving the problems of food insecurity and malconsumption in a warming world.

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