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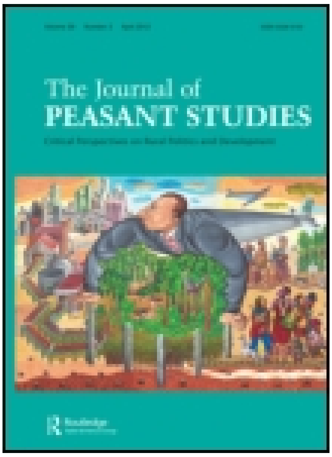

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The meat of the global food crisis

Tony Weis

The global food crisis has been widely described in terms of the volatility of grain and oilseed markets and the associated worsening conditions of food security facing many poor people. Various explanations have been given for this volatility, including increasingly meat-centered diets and rising demand for animal feed, especially in China. This is a very partial reading, as the food crisis runs much deeper than recent market turbulence; when it is understood in terms of the biophysical contradictions of the industrial grain–oilseed–livestock complex and how they are now accelerating, meat moves to the center of the story. Industrial livestock production is the driving force behind rising meat consumption on a world scale, and the process of cycling great volumes of industrial grains and oilseeds through soaring populations of concentrated animals serves to magnify the land and resource budgets, pollution, and greenhouse gas emissions associated with agriculture. These dynamics not only reflect disparities but are exacerbating them, foremost through climate change. Thus, this paper suggests that rising meat consumption and industrial livestock production should be understood together to comprise a powerful long-term vector of global inequality.

Keywords: industrial livestock; food crisis; global inequality

Meat and dietary change in the 'food crisis'

From 2006 to 2008, world market prices of grains, oilseeds, and cooking oils spiked on a scale not seen since the early 1970s. This led to sharp increases in levels of food insecurity, malnutrition, and poverty, particularly in South Asia and Africa, and to food-centred riots in many countries. According to FAO (2009a) estimates, the population of undernourished people jumped above one billion following decades-long stability between 800 and 900 million people,[1] a further blow to the vanishing Millennium Development Goal that this number would be cut to 400 million by 2015. As food prices stabilized in 2009, some commentators suggested that the crisis had passed, before renewed volatility and even higher price spikes hit again, and reached new highs in 2012. The combination of recurring food price volatility and its uneven social fallout is widely marked by talk of a new 'global food crisis'.

I would like to thank Philippe le Billon, Jamey Essex, and Melanie Sommerville for helpful feedback following the special session on the food crisis they organized at the Annual Meeting of the American Association of Geographers in Seattle in April 2011. I am also grateful for the comments given by anonymous reviewers at the *JPS*.

[1] Given the rising total population, this did represent a steady decline relative to the total global population since the early 1970s, from 26 to 13 percent.

Fast-rising meat consumption in industrializing countries, especially in China and parts of Asia, has been regularly cited as a cause of world food price volatility, sometimes coded simply as affluence-related 'dietary change', with industrial livestock production pulling heavily on grain and oilseed supplies for feed (Jarosz 2009).[2] However, some assessments have downplayed the impact that this demand has had on world food prices (UN 2009), and in general most attempts to place meat in the food crisis have been very partial, while the surging usage of grains and oilseeds in industrial agrofuel production has featured more prominently in explanations of food price volatility and generated more moral outrage.[3] One stark reflection of this can be seen in the recurrent criticism heaped upon the Renewable Fuel Standard (RFS) in the US, which mandates that one-tenth of the gasoline pool of fuel companies must come from ethanol, thereby directing roughly two-fifths of US maize to agro-fuel production (with a spillover effect on the area planted in other crops). This criticism reached a fever pitch in 2012 as prices of important commodities shot up amidst the severe drought and crop damage across much of the US, and led some House representatives, senators, and state governors to call for a two-year moratorium on the RFS, alongside a coalition of leading organizations in the industrial livestock sector (Blas and Meyer 2012).[4] On a wider scale, the director-general of the FAO connected fears about US production shortfalls to risks of world food and feed price volatility and made an appeal to either lower or suspend the RFS, pointing to the role that agro-fuels had in the 2007–2008 price spikes (Graziano da Silva 2012).

Although we must be concerned about the causes and impacts of short-term market turbulence, it is important not to exaggerate the stability that preceded it. World food security has increasingly come to pivot on the cheap surpluses of the industrial grain–oilseed–livestock complex, which rests upon a precarious biophysical foundation and an illusion of efficiency (Friedmann 1993, 2005, Weis 2007). This foundation, and the illusion that surrounds it, are becoming less stable with converging problems of soil erosion, diminishing freshwater availability, the decline of key non-renewable resources, and climate change, at the same time as this system is an important factor causing climate change. As these biophysical contradictions

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[2] Other explanations include the fast-rising production of agrofuels from industrial grains and oilseeds, and their role drawing down global reserves and influencing the area planted in different grains; changing stock-to-use ratios and the lack of transparent management of grain reserves; fluctuating oil and agro-input prices; the increasing presence of speculative capital in agricultural futures and investment; drought-affected production shocks to some key surplus exporters; export restraints levied by some countries; and renewed Malthusian fears (some examples include Nellemann *et al.* 2008, Bello 2009, Brown 2009, 2011, FAO 2009a, Headey and Fan 2010). Champions of corporate–industrial agriculture and neoliberalism have tended to blame food price volatility on incomplete liberalization and state interference in markets, with key objects of criticism being agrofuel subsidies, export restraints, and restrictive intellectual property rights (Paarlberg 2010).

[3] For instance, Bello (2009, 105) cites a number of different estimates of the degree to which this demand was responsible for world food price spikes between 2006–2008, ranging from 20–75 percent, as given by the IMF, World Bank, OECD, and Oxfam.

[4] With this, the RFS can be seen to have become an increasingly significant lightning rod amidst the competing factions (divided by region and segments of agricultural capital) which ultimately give shape to US farm policy, as Winders (2009) has shown so well. In essence, farmers in the US 'Corn Belt' want to maintain the higher prices that the RFS mandate helps stoke, while major livestock producing regions worry about its impact on the rising cost of feed (Blas and Meyer 2012).

accelerate, once-cheap industrial foods are bound to become more expensive, with human impacts poised to play out in highly unequal ways (Weis 2010a).

This paper argues that uneven and rising meat consumption on a world scale – and its driving force, industrial livestock production – must be seen as a central, inescapable part of this deeper food crisis, which extends far beyond rising demand in Asia. Industrial livestock production exerts a large and growing 'ecological hoofprint', a concept which calls attention to the multidimensional resource budget and environmental burden associated with cycling massive volumes of industrial grains and oilseeds through rising populations of concentrated animals (Weis 2010b). It also helps to show how the nature and trajectory of industrial livestock production is a powerful vector of global inequality tied to both entrenched and shifting disparities in resource consumption, pollution, and emissions which are actively undermining long-term prospects for development, principally through climate change. The impacts and inequalities associated with food import dependence and price volatility in world markets are ever more accentuated as the biophysical basis of world agriculture is destabilized.

Yet the race towards greater meat consumption continues to be widely taken for granted, and uncritical projections that meat consumption will continue rising significantly are embedded in claims that world food demand will double by 2050 and in claims that enhanced yield (especially in poor, 'under-yielding' countries) is therefore needed to solve present and future food problems (Tilman *et al*. 2011). Such depictions of an asymmetrically under-yielding planet with a 'yield gap' (Neumann *et al*. 2010) must be replaced, I argue, with the recognition that enormous volumes of grains and oilseeds are being inefficiently cycled through concentrated livestock to serve an asymmetrically 'meaty' planet, a process that both reflects and exacerbates global inequality. From this perspective, the need to challenge and reverse the race towards greater meat consumption emerges as an essential aspect of struggles for a more equitable and sustainable world, starting with the prospect of mitigating the magnitude of climate change impacts.

The uneven geography of meat: an overview

Rising meat production and consumption has long been one of the most powerful trends in world agriculture. This is reflected in the 'meatification' of diets, a term which encapsulates the dramatic shift of animal flesh and derivatives from the periphery of human food consumption patterns, where it was for most of the history of agriculture, to the centre (Weis 2007). The average person on earth consumed 42 kg of meat in 2009, almost double the per capita world average in 1961 (23 kg), along with twice the eggs (from 5 to 10 kg). This transformation must also be set against the fact that human population leapt from three to seven billion over this time, which translates into a four-fold increase in world meat and egg production in a mere half-century. Amidst rising volumes, the relative share of total meat production that is internationally traded has also crept steadily upwards over the past century, from 5 to 13 percent.[5]

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[5] The production and trade statistics in this paper have been summarized from FAO Statistics database (FAOSTAT 2012). National statistics for meat consumption were derived by adding production and imports together and subtracting exports. At the time of writing, trade statistics were available up to 2009, and production statistics up to 2010.

Although rising meat consumption has been a broad global trend, it is marked by extreme disparities. At the apex of the global animal 'protein ladder' are the temperate heartlands of the industrial grain–oilseed–livestock complex, led by the US (120 kg per capita in 2009), Australia and New Zealand (118 kg), Argentina (113 kg), Canada (102 kg), and Western Europe (85 kg).[6] Taken together, these countries are home to only 12 percent of the world population and yet accounted for 34 percent of world meat production by volume in 2009, along with 30 percent of total meat consumption and 68 percent of world exports. At the other end of the meat consumption spectrum are Southeast Asia (27 kg per capita in 2009), Africa (18 kg), and South Asia (7 kg), which are home to almost half of humanity but under one-sixth of world meat consumption and production in 2009, keeping in mind that low national per capita averages conceal class disparities in consumption.

In between these poles is where the greatest change has occurred over the past half-century, especially in China and Brazil. From 1961 to 2009, per capita meat consumption rose from 4 kg to 59 kg in China and from 28 to 73 kg in Brazil, with total meat production increasing 31-fold in China and 11-fold in Brazil. In 1961, China and Brazil represented 24 percent of humanity and accounted for less than seven percent of world meat production by volume, but by 2009, with a similar share of humanity, they produced 33 percent of all meat in the world. Brazil has recently emerged as the second largest meat exporting country, and the largest exporter of beef, with its meat exports quadrupling by volume from 2000 to 2009 alone (during which time its share of the world meat exports rose from 6 to 16 percent). Figure 1 portrays per capita trends and Figure 2 highlights changes in total production over the past 50 years.

This shifting geography of meat is entwined with rising flows of feed grains and oilseeds. Whereas small livestock populations historically grazed on fallowed land and small pastures, scavenged around farm households, and sometimes fed on locally produced forage stored over winters, fast-rising populations of industrially-reared livestock are being raised on feed that has frequently moved across large distances, both within countries and even across borders. On a world scale, the large majority of coarse grains, soybeans, and rapeseed/canola are fed to livestock. In 2009, almost 446 million ha of these crops were harvested, covering roughly one-third of the world's total harvested land area and representing a 30 percent increase over the past half-century, in step with the growth in the world's total harvested area. This means that livestock effectively occupy a significant share of the 10 percent of the earth's land area that is in cultivation, in addition to the roughly 25 percent of the earth's land area that is in pasture, some of which would be suitable for permanent crops and some of which can only bear very low stocking densities, as throughout most of the tropics, and should never have been converted to pastures (Steinfeld *et al.* 2006).

On a world scale, the areal expansion of feed crops has been primarily concentrated on maize and soybeans. From 1961 to 2009, the area devoted to maize increased by 50 percent and the area devoted to soybeans more than quadrupled, while the area devoted to most other feed crops was relatively stagnant. This has been augmented by large yield gains, which are in turn tied to tremendous input

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[6] This includes FAO groupings of North, South, and West Europe, but not Eastern Europe, where the demise of the Soviet bloc led to a dramatic fall in consumption in the 1990s before beginning to rise again after 2000.

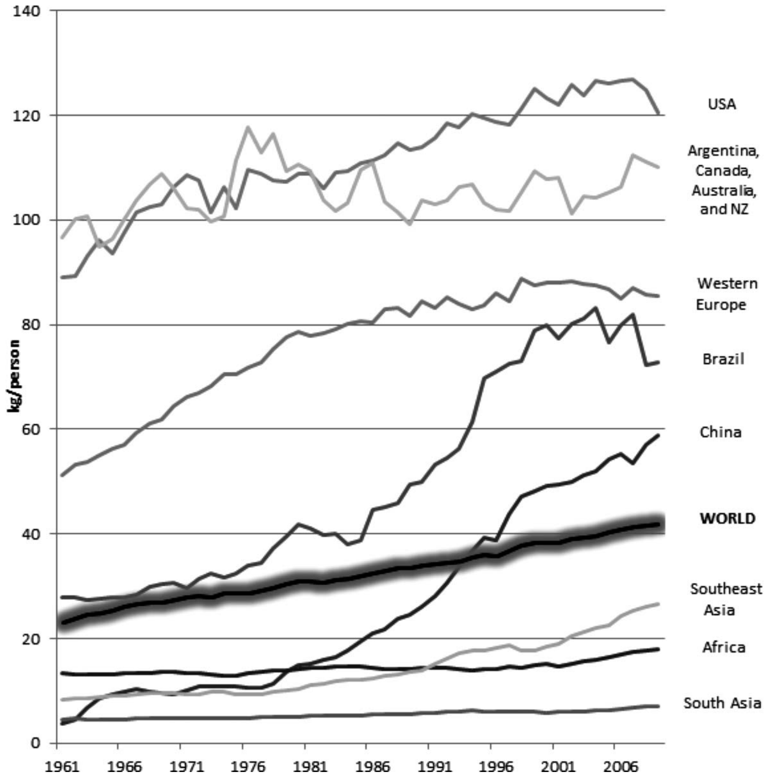

Figure 1. Meat consumption per capita, selected examples, 1961–2009.
Source: FAOSTATS.

useage, with the net result being that world maize production more than quadrupled and soybean production grew more than eight-fold in a half century. Maize and soybeans are the two predominant feed crops that are traded internationally. Since 1961, the volume of maize exports grew seven-fold and world soybean exports grew eight-fold; more than one-third of all soybean production is now exported. The US was the dominant exporter of both maize and soybeans for many decades, with soybeans principally flowing to Western Europe. However, this began changing in the late 1990s as Brazil and Argentina rushed to expand soybean production and exports, and China's demand for imported feed began climbing with its fast-rising meat production (see Figure 2). From 1990 to 2009, Brazil's soybean exports leapt from 4 to 29 million tonnes, while China's soybean imports spiked from 2 to 45 million tonnes, comprising more than half the world total in 2009.

Another important dimension of the uneven geography of meat relates to animal populations and living conditions. The meatification of diets – which reflects the degree to which production has outpaced human population growth – has overwhelmingly centered on pigs and poultry. In 1961, cattle accounted for almost two-fifths of world meat production by volume, followed by pig (35 percent), poultry (13 percent), and sheep and goats (8 percent). In the subsequent half century, the human population grew by 120 percent while the annual volume of pig meat produced more than quadrupled and the volume of poultry meat grew more than 10-fold. The net result was a dramatic change in the relative volumes by 2010, with pig

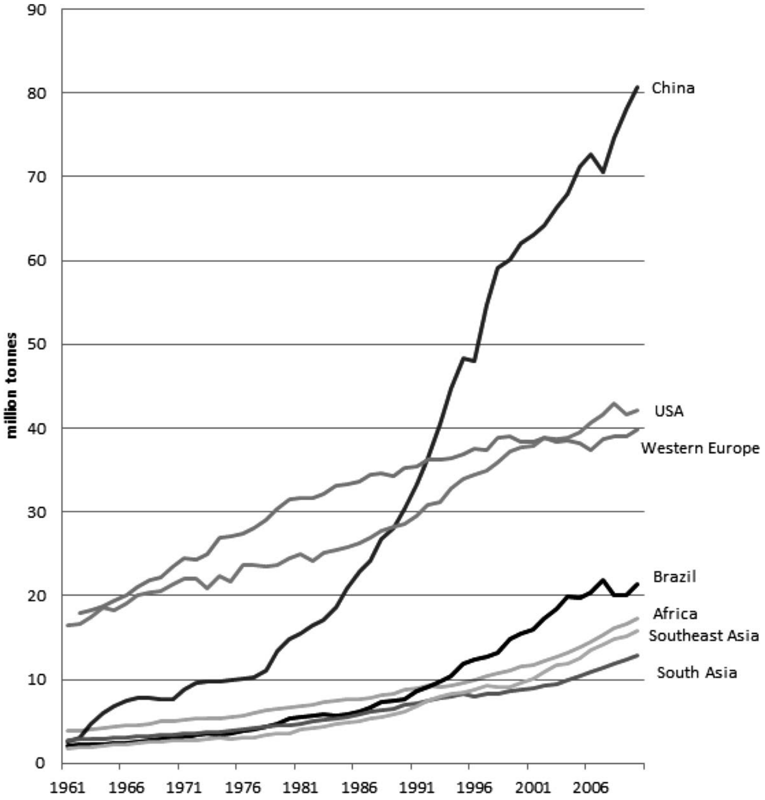

Figure 2. World meat production by volume, 1961–2009.
Source: FAOSTATS.

(37 percent) and poultry (34 percent, predominantly chicken) now clearly at the forefront of world meat production, followed by cattle (21 percent) and sheep and goats (5 percent). Poultry is also the leading force behind rising world meat exports, jumping from 20 percent to 38 percent of world meat exports between 1990 and 2009.

In *Livestock's long shadow*, it was estimated that more than half of all pig meat and 70 percent of all poultry meat in the world were produced in intensive production systems, accompanied by growth in semi-intensive forms of production at intermediate scales (Steinfeld *et al.* 2006). Broad global patterns of intensive poultry and pig production evident in 2005 are seen in Figure 3. From 2005 to 2010 world pig meat production increased by a further 10 percent while world poultry production shot up by 21 percent. Because birds are much smaller than other major livestock, grow to slaughter-weight the quickest, and are the most intensively farmed of any animal, it means that these volume increases translate into a staggering number of animal lives, an increasingly large majority of which are spent in conditions of extreme confinement and suffering. Chickens accounted for almost 53 billion of the more than 60 billion animals slaughtered in 2009, in comparison to 1.3 billion pigs and 300 million cattle. Continued growth in per capita meat consumption is projected in the coming decades, with the fastest growth expected in China and other rapidly industrializing countries, and the burgeoning upper and middle classes within them. The FAO estimates that world meat production will rise

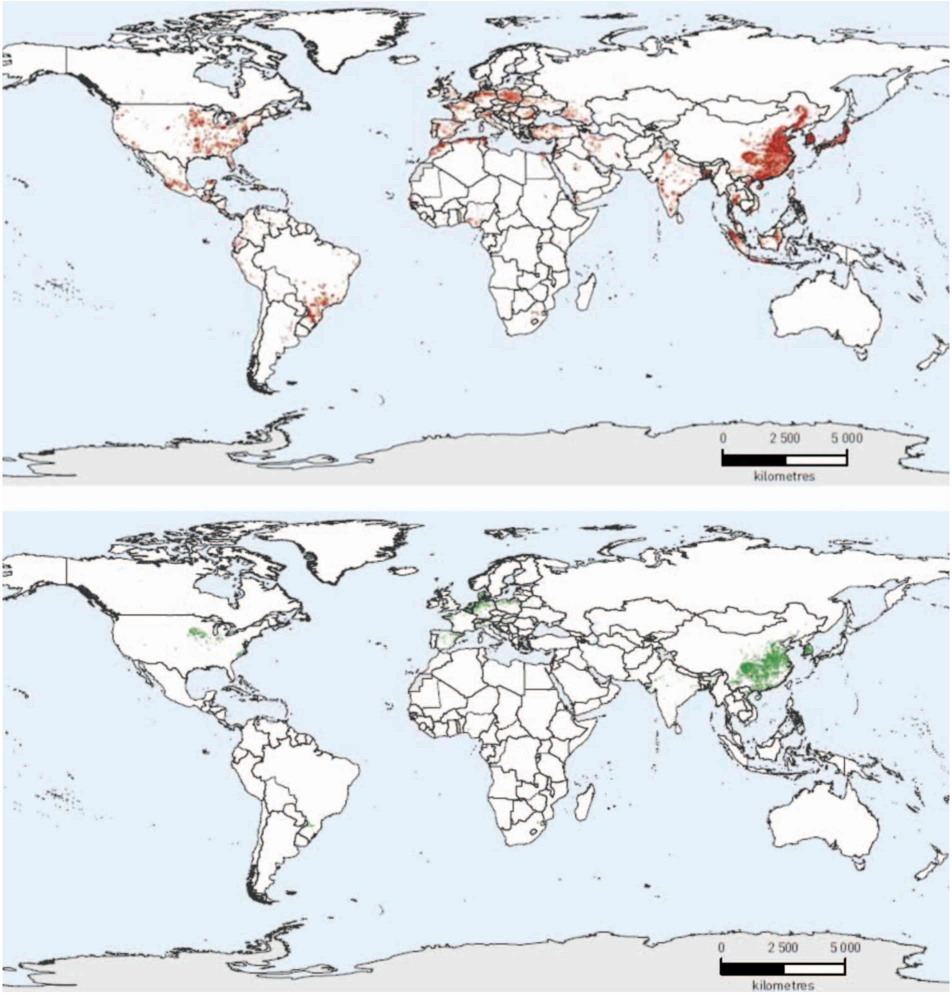

Figure 3. Global distribution of intensive poultry (top) and pig (below) production systems, 2005.
Source: Robinson *et al.* (2011, 55–56).

to 52 kg per person by 2050, which in a world of 9.3 billion people would mean over 480 million tonnes – versus 293 million tonnes in 2010 (42.5 kg per capita). Industrial livestock production is expected to account for virtually all of this future global growth, and because poultry is projected to remain at the forefront, the annual population of slaughtered animals could approach 120 billion (Nierenberg 2005, Steinfield *et al.* 2006, D'Silva and Webster 2010, FAO 2011a, b, Robinson *et al.* 2011). Continuation on this trajectory is bound to intensify the demand for industrial grains and oilseeds as feed.

Dependence on cheap food imports

As noted, the world's poorest countries tend to have the lowest levels of per capita meat consumption in the world. They also have by far the highest shares of their population engaged in farming. For instance, roughly half of the total population in South Asia and Africa was agricultural in 2010, a share which rises to close to two-thirds in the world's Least Developed Countries. Africa, South Asia, and Southeast Asia also dominate IFPRI's 'hot spots' of world hunger, and the FAO's categorization of Low Income Food Deficit Countries (LIFDCs). Over the course of decades, food security in these regions has increasingly come to hinge on the importation of cheap grains, principally wheat and secondarily maize and rice. For the LIFDC's as a whole, wheat has long comprised over two-thirds of total cereal imports.[7]

Although countries of the Global South imported very little food at the point of independence, the subsequent rise in food import dependence must nevertheless be seen partly in light of the landed inequalities and economic rut carved by colonialism (Weis 2007). Central to this was the fact that a narrow range of tropical agro-exports (e.g. sugar, cotton, coffee, tea, cocoa, palm oil) tended to dominate significant areas of the best arable land, which became increasingly problematic in the face of declining terms of trade that owed to both structural overproduction and increasing substitution by temperate crops (Robbins 2003). The other major dimension of rising food import dependence stemmed from the mounting surpluses of increasingly industrialized, input-intensive agricultural production in temperate countries, most significantly the US, where the need to find export outlets translated into extensive programs of food aid and subsidized trade (Berlan 1991, Friedmann 1993, Winders 2009). This cheap food was celebrated by development planners and welcomed by recipient governments as a means to help foster urbanization and industrialization (a key part of a general development policy 'bias' to urban areas), and served to commoditize food security, reconfigure diets, and place new pressures on small farming livelihoods (Friedmann 1990).

As small farmers faced deflated prices in domestic markets, many were themselves becoming tied to food imports to some degree. These competitive pressures were rooted not only in industrialized economies of scale and extensive state subsidy regimes, but in an assortment of externalized costs that might be understood as implicit subsidies (Weis 2010a). This general path towards rising food import dependence was further entrenched by the myriad debt crises that began unfolding across the South in the 1980s. The burden of debt service together with structural adjustment prescriptions significantly reduced the role of the state in agriculture, forcing extensive cuts to government expenditures on research capacity, extension services, small farm oriented credit, and rural and domestic marketing infrastructure, while diffusing energy for state-led redistributive land reforms, promoting agro-export expansion, and liberalizing domestic markets, with liberalization further entrenched after 1995 by the multilateral disciplines of the WTO (Rosset 2006, Weis 2007, Bello 2009). Part of the ideological justification for this set of policies was known as the 'free market approach to food security', essentially an assurance that increased exports and liberalization together enhance foreign

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[7] In 2012, the FAO listed 66 countries as LIFDCs, 39 of them in Sub-Saharan Africa. This listing is based on a low Gross National Income and an assessment of the average net food trade, considering trade volumes and an estimation of their caloric content over the preceding three years. Countries can choose to exclude themselves from this listing. This focus should not imply that vulnerability to world market price shocks is only present in the world's LIFDC's, only that it is generally greatest there.

exchange earnings and the ability to access the bounty of global food markets, bringing lower prices and more stable supplies.

Underlying these assurances was the false assumption that world markets will perpetually abound with cheap food surpluses, which has continuously ignored the biophysical contradictions of the industrial grain–oilseed–livestock complex and the long-term resource constraints and climatic burden associated with tying food security strategies to vast, permanent material flows over great distances. The vulnerability laden in this for poor countries was partially masked as long as cheap industrial surpluses flowed, but is becoming more and more evident amidst the volatility in world food markets.

The instabilities and illusory efficiency of the industrial grain–oilseed–livestock complex

The industrial grain–oilseed–livestock complex involves a profound reconfiguration of agriculture's historic organizing imperatives. Through most of agrarian history, agroecosystems had to be organized in highly localized ways, based upon functional diversity, complementarity, and relatively closed-loop material cycles, in order to manage short-term risks and maintain future soil health. This tended to include small and varied livestock populations grazing, scavenging and cycling wastes, and put to work as traction on farms. Mechanization and the pursuit of economies of scale demolished agriculture's historic organizing imperatives, and substituted an entirely different organizational logic: biological simplification and standardization. In order to enable mechanization, large volumes of the same thing must be planted and harvested together. As a result, small and varied livestock populations became not merely a nuisance but a barrier to scale, and the need to push animals off farmland has gone hand-in-hand with the revolutionary intensification of livestock production.

The expansion and industrialization of grain and oilseed production and the expansion and industrialization of livestock production have been mutually reinforcing: rising crop productivity enabled livestock populations to grow far beyond former densities on smaller, more biodiverse farms, while rising livestock populations enabled crop production to grow to an extent that would otherwise have deflated prices and undercut incentives. In other words, increasing livestock populations were not only about increasing value-added opportunities in animal flesh, milk, and eggs, but were also about transforming structural grain and oilseed surpluses from a deflationary millstone into a steadily growing source of low margin earnings for large-scale farmers, processors, and traders (Berlan 1991, Winders and Nibert 2004).[8]

The productive environments of the industrial grain–oilseed–livestock complex are characterized by a structural dualism – expansive monoculture fields dotted by spaces of concentrated livestock – that is shaped by a unitary logic. Throughout the

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[8] Although the explosive growth of industrial livestock has helped to lessen the problem of surplus grain absorption for large-scale producers, it has never fully resolved it, and surplus management has been a major factor in enduring subsidy regimes in the US and EU. Industrial agrofuels conceivably have an almost limitless absorption capacity, given the enormity of grains and oilseeds that are needed to produce a volume of ethanol or biodiesel that could substitute for oil on any significant scale. However, given the low energy return on energy investment (EROI), any large-scale substitution is filled with momentous contradictions (Giampietro and Mayumi 2009, Houtart 2010).

temperate heartlands of this system, production is focused on a small number of grains (mainly maize, wheat, and a few secondary coarse grains), oilseeds (mainly soybeans and rapeseed/canola), and animals (pigs, poultry, and cattle). Crops and animals are disarticulated between fields, factory farms, and feedlots, with complementarity and biological cycles broken, and then re-articulated through continuous flows of feed and, as emphasized below, many other resources. These dynamics of scale, simplification, and standardization have long been assumed to promote efficiency, with the decisive evidence being the cheapness of industrial foods. But this cheapness has been a great illusion, which is now beginning to crack. Part of the illusion of cheap industrial food stems from the impact of agricultural subsidy regimes in industrialized countries (Rosset 2006, Weis 2007). However, an even more fundamental illusion stems from how the pursuit of economies of scale and the need for simplified and standardized environments systematically undermine the biological and physical foundations of agriculture, depend on the unsustainable use of non-renewable resources, particularly fossil energy, and generate large pollution loads and greenhouse gas (GHG) emissions (Weis 2010a).

The organizational imperatives of industrial agriculture create or exacerbate many biophysical problems. Soil degradation is an age-old challenge, but it is greatly accelerated by industrialization and the disarticulation of animals from land, compaction by large machinery, diminished soil organisms, and reduced vegetative ground-cover in monocultures. Monocultures simultaneously widen the classification of undesirable species as pests while increasing the conditions for them to spread in large homogenous fields with impoverished soils and decimated predator populations. The replacement of labour and animal traction with machines and the movement of inputs and outputs over greater distances drastically increases the energy needed for agriculture. Enhanced seeds and soils with less biota, ground-cover, and moisture retention also heighten irrigation demands, and are thus implicated in great freshwater diversions and the pumping of underground supplies. The general systemic response to the range of biological and physical problems has been to overpower them with a series of external inputs, or what might be seen as *biophysical overrides*, which are indispensable to economies of scale in agriculture. The problem of soil degradation is primarily overridden with inorganic fertilizers, mainly to replace depleted nitrogen, phosphorous, and potassium. The problems posed by weeds, insects, fungi, and plant disease are overridden by a treadmill of chemical pesticides, which engenders and must adjust to new threats over time as natural controls are eliminated, soil health declines, and resistance develops. Increased water demands have been met by engineering projects on a range of scales and the pumping of underground aquifers, frequently above rates of recharge. This array of biophysical overrides must then be understood in the context of their resource budgets, pollution burdens, and intractable dependence upon fossil energy (McIntyre *et al*. 2009, Weis 2010a).

Fossil energy is the lifeblood of large machinery, the long-distance movement of inputs to farms and outputs from them, and, less visibly, the production of essential overrides, including fertilizers and pesticides. In powering mechanization, fertilizer production, and long-distance material flows, fossil energy is systematically linked to both the degradation of soils and the manufacture of a few key nutrients which are injected back into agricultural production. Synthetic nitrogen fertilizers are predominantly manufactured through the Haber–Bosch process for combining atmospheric nitrogen and hydrogen, with natural gas the main feedstocks. The energy budget of phosphorous and potassium fertilizer production extends from fossil fuel-powered mining machinery to the electricity in large processing plants. The bulkiness of fertilizers also means that a great amount of energy is needed to move them from factories and mines to farms. Pesticides are commonly derived from petrochemicals, and like fertilizers contain an under-accounted energy budget from manufacturing to transport to application. Moving water against gravity is another commonly discounted energy demand, from the macro-scale mining of underground aquifers to generators pumping micro-scale systems. This wide-ranging fossil energy budget generates a large volume of carbon dioxide emissions, and synthetic nitrogen fertilizer is an important source of another GHG, nitrous oxide. Further, the atmospheric impact of industrial monocultures also relates to how the reduced biomass in plants and in soils (relative to both natural ecosystems and more biodiverse farms) diminishes the capacity for carbon sequestration over a given area of land. In addition to climate change, this system is implicated in a range of other environmental problems, with some of the most damaging being: the runoff of excess nutrients from industrial fertilizers, which causes widespread eutrophication and damage to freshwater and coastal ecosystems; the persistent toxins that stem from the pesticide treadmill, which pose complex and diffuse risks for ecosystems, animal life, and human health; and the land degradation caused by prolonged irrigation and waterlogging, nutrient leaching, and salinization (Kimbrell 2002, Nellemann *et al.* 2008, Shiva 2008, Schindler and Vallentyne 2008, McIntyre *et al.* 2009).

In short, the cheapness of industrial grains and oilseeds has rested not on the triumph of efficiency, but on a host of hidden and externalized costs, or implicit subsidies, which should be added to the price-distorting effect of explicit government subsidies (Weis 2010a).

The ecological hoofprint and the magnifying effect of industrial livestock

The ecological hoofprint is a framework for conceptualizing the resource budget and multi-dimensional environmental burden of industrial livestock, in particular how its growth is implicated in an expansion of the land area, input and energy consumption, GHG emissions, and pollution load of industrial monocultures. Through this, and in light of the scale, growth, and marked inequalities in meat consumption examined earlier, the ecological hoofprint also draws attention to how this trajectory constitutes a major vector of global inequality.

As a result of the nutrients burned in animal's metabolic processes, the cycling of grains and oilseeds through livestock to produce flesh, eggs, and milk is an inherently inefficient way to produce food. In *Diet for a small planet*, Lappé (1991/1971) first called attention to the essential regressivity and environmental implications of this feed conversion inefficiency, describing grain-fed livestock as 'reverse protein factories' due to the protein consumed and turned into various wastes, a point which holds more generally for useable nutrition. Different animals have different conversion ratios, contingent on breeds, feed regimes, conditions of confinement, and antibiotic and hormonal cocktails, but in general poultry are the most efficient – or, more accurately, least *in*efficient – followed by pigs, with cattle the worst.

As discussed, these metabolic losses have an economic logic, as the value-added opportunities in livestock production greatly expand the size of the market for grain and oilseed surpluses, though still at exceptionally small margins made viable largely by farmers growing in scale and shrinking in numbers, alongside subsidy regimes skewed to large-scale producers. But while the destruction of large volumes of useable nutrition in grains and oilseeds can be profitable, industrial livestock production is similarly disciplined by intense competition and thin margins, which has produced two basic pressures: to enhance conversion ratios and to increase the scale of production, while feed-to-flesh conversion ratios are also reflected in the major shift in global meat production towards pigs and especially poultry described earlier. These pressures weave together in ever-larger sites of production and rising animal densities and confinement, which at once reduces the feed 'lost' to metabolic processes (as immobilized animals in controlled environments burn less energy) and makes it easier for capital to replace labour. Rising livestock densities have gone together with large increases in the yield and the 'turnover time' of individual animals, radically shortening animal lifespans from those on traditional mixed farms (Mason and Singer 1990, Boyd and Watts 1997, Boyd 2001, D'Silva and Webster 2010). As the leading site of industrial livestock production and home to many of the key corporations leading its innovation, the US illustrates how fewer sites with larger animal numbers have come to dominate overall production. In 2007, 89 percent of all meat chicken sales in the US came from just over 11,300 farms that each sold an average of almost 700,000 birds per year, and 87 percent of all pigs sold came from less than 8000 farms that sold an average of over 22,600 animals per year, while the total number of farmers raising pigs fell almost six-fold from 1978 to 2007 (USDA NASS 2008).

However, as with industrial monocultures, economies of scale are extremely problematic, as the industrialization of livestock involves another array of biophysical instabilities and overrides. Animals do not easily accommodate the process of mechanization and the attendant crowding, confinement, sensory deprivation, stench, and constant noise, which heighten animal stress, behavioural pathologies, and disease risks (e.g. swine and avian flu, listeriosis, and E. coli). Much as with monocultures, the response to systemic problems has been to overpower them. The health and stress problems arising from unnatural densities are mainly overridden through a combination of proliferating pharmaceuticals, chemical disinfectants, and routine physical mutilations. The development of these overrides has been concurrent with constant capitalist innovation geared at pushing biophysical boundaries and improving feed conversion ratios through genetic 'enhancement', engineered environments, sub-therapeutic levels of antibiotics, and in some cases hormones – as well as through externalized environmental costs and animal suffering. For instance, poultry bodies engineered to add flesh quickly literally outgrow their skeletal development, leaving many birds in chronic pain and unable to perform elemental acts, an extreme reflection of which is the fact that industrial turkey breeds cannot physically reproduce. The suffering and violence inflicted upon animals in systems of industrial production involves important questions about humanity's relationship and responsibilities to other species, and the brutal treatment of animals translates into wretched work process (Mason and Singer 1990, Boyd and Watts 1997, Boyd 2001).

Yet while innovations have enabled animal bodies to grow much faster, produce more milk and eggs, and yield more with less feed than in the past, there are inevitable biological limits to how far this can go. Four decades after it was first published, Lappé's (1991) essential point remains: a given volume of useable nutrition can be produced on a much smaller land and resource budget when derived directly from grains, oilseeds, or other plant-based sources than when crops are cycled through livestock, as large shares of edible nutrition are lost in animals' metabolic process. These nutritional losses due to the inherent inefficiency of cycling feed through animals to produce food are very well-established, as is the fact that they serve to magnify the ecological footprint of industrial monocultures, forcing more land area to be devoted to their production, and with it more fertilizers, chemicals, freshwater consumption and diversions, and fuel, and in turn generate more GHG emissions and pollution loads while diminishing carbon sequestration capacity (Goodland 1997, White 2000, Gilland 2002, Leitzmann 2003, Pimentel and Pimentel 2003, York and Gossard 2004).

Added to this are the resource budgets and pollution burdens associated with industrial livestock operations and processing. The expansion of factory farms increases the energy needed for temperature control, venting, lighting, and waste management, while the growing scale and centralization of slaughter and packing plants increases the energy needed for processing and transport, as many more animals are moving across greater distances. This expands further if the energy needed in post-production storage and preparation is considered, as flesh, eggs, and milk tend to have much greater refrigeration and cooking demands than do most other foodstuffs, particularly grains and oilseeds.

Factory farms, feedlots, and processing plants are also heavy consumers and polluters of water. Whereas small livestock populations historically drew water on or near farms and through plants, industrial livestock production expands the pull on water for animal intake and for cleaning factory farms and slaughterhouses, as well as through the 'virtual water' embedded in feed (i.e. used in the production of grains and oilseeds) which is again magnified by conversion inefficiencies. In contrast to the functional role of small livestock populations within integrated farming systems, recycling nutrients on fallowed land and small pastures, massive concentrations of animals generate faecal waste on a scale far greater than can be absorbed in nearby landscapes, compounded by the fact that it is laden with residues from antibiotics, hormones, and agro-chemicals from feed. Some of this faecal waste is turned into fertilizer and some is contained in reeking lagoons, but inevitably some escapes into the ground and into freshwater ecosystems, contributing to eutrophication problems and downstream health problems (Steinfeld *et al.* 2006, Pew Commission 2008, Schindler and Vallentyne 2008).[9]

When the resource budgets from confinement to slaughter are added to the resource budgets and conversion inefficiencies associated with cycling industrial grains and oilseeds through animals, it is estimated that eight times more fossil energy and 100 times more water goes into a unit of edible protein contained in factory-farmed meat in the US than goes into a unit of edible protein in industrial grain (WorldWatch 2004, Nierenberg 2005). The burden of this energy budget is extended by the role of livestock in the continuing conversion of biodiverse ecosystems for more pasture and feed crops, which releases carbon dioxide in the short-term and reduces the capacity for carbon sequestration over the long-term. This dynamic is most destructive across Amazonia, where cattle ranching remains a major force in deforestation, and has recently been augmented by industrial soybean

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[9] The severe environmental, health, and aesthetic impacts, such as wreaking 'smell-scapes', has led to community resistance to large industrial livestock operations in some instances. This is widely recognized as one reason why some industrial livestock production in the US has gravitated towards poorer regions in pockets of the South and Midwest.

production that is mainly used for feed (Hecht 2005, Barreto *et al.* 2007). The world's ruminant population is also a large source of methane, another important GHG. When these impacts are taken together, the global expansion of livestock production is recognized as one of primary causes of climate change, responsible for almost one-fifth of global anthropogenic emissions by the most commonly cited estimate (Steinfield *et al.* 2006, IPCC 2007, McMichael *et al.* 2007, McIntyre *et al.* 2009).

Accelerating instabilities: risks and regressivity

The chronic biophysical contradictions described in the preceding sections are now accelerating due to an array of factors including: soil erosion; pest resistance to chemical treadmills; the over-pumping of underground aquifers; the approaching limits to the world's supply of easy oil (or peak oil) and other key resources; and climate change (Pimentel 2006, IPCC 2007, Nellemann *et al.* 2008, Moore 2010, Weis 2010a, FAO 2011c). Peak oil and climate change are at the forefront of these instabilities. The limits to conventional oil supplies and the increasing dependence upon more expensive extraction sites mean that while oil prices might remain volatile in the short-term, they are bound to increase in the longer term. This pressure is pulling industrial grain and oilseed production in two basic and opposing ways. First, rising oil prices inevitably translate into rising costs through the running of machinery and factory farms, the production of key biophysical overrides which underpin high-yielding crops and animals (further exacerbated by the declining supply of the world's phosphate rock reserves[10]), and the movements of inputs and outputs across long distances, together breaking down some of the powerful, implicit subsidies that have long underpinned cheap food. Yet even as biophysical instabilities worsen, industrial grain and oilseed production are being emboldened by the agrofuel boom, which is driven by the intense push for new sources of liquid energy, powerful corporate interests, and state subsidies. Given the large surplus absorption capacity of agrofuels (relating to the low EROI noted earlier), they are bound to place pressure on world grain and oilseed markets, while the vast land area demanded threatens to exacerbate climate change through emissions associated with land clearance and through diminished sequestration capacity (Righelato and Spracklen 2007, Giampietro and Mayumi 2009, Houtart 2010).

In addition to being a major factor in climate change, the industrial grain–oilseed–livestock complex also faces considerable risks from it. Models of yield responses to climate change are extremely complex, as they involve a host of variables and interactions, and a scale of change beyond what has ever been experienced during the 10,000 year history of agriculture. At lower levels of change, below what is conventionally defined as the 'safe' target for global average temperature increase (2°C above pre-industrial levels), there is a possibility that warmer temperatures might extend growing seasons in the world's temperate regions, especially on the cooler margins, and thereby enhance agricultural

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[10] Phosphate rock is the main source of phosphorous used in industrial fertilizers, and reserves are declining and could be gone within the next 50 to 100 years. As high quality reserves decline, extraction and processing becomes more expensive and shipping distances are growing, increasing energy demands, costs, and environmental impacts. Although there are considerable uncertainties about the absolute supply limits (and hence precise timelines), concern has been sometimes dubbed 'peak phosphorous' (Cordell *et al.* 2009, Cordell and White 2011).

productivity and expand the arable land area. But there is also a possibility that such potential gains could be cancelled out, or worse, by new dynamics, including projections that climate change is likely to: enhance conditions for the movement and reproduction of pests, pathogens, and invasive species; reduce freshwater availability due to changing precipitation patterns reduced river runoff; increase evaporation and reduce soil moisture; and heighten risks of heat waves and droughts amidst declining water availability, especially in drier mid-latitude areas (Schmidhuber and Tubiello 2007, Nellemann *et al*. 2008, McIntyre *et al*. 2009, Hertel *et al*. 2010, FAO 2011c).[11] There are growing fears that yields may be far more sensitive to temperature increases than previous thought, and recent droughts in some of the world's grain and livestock heartlands (e.g. Australia, Argentina, the Indian Punjab, Canada, Russia, Ukraine, and the US) give serious cause for concern about the risks of elevated heat and aridity in the world's great surplus-producing regions.

However, many of the world's poorest countries with the smallest atmospheric footprints are projected to face the most adverse impacts even at at lower levels of climate change, well within ostensibly 'safe' global targets. These threats stem from the prospect of hotter average temperatures, more severe weather events (e.g. heat waves, droughts, and tropical storms), more variable rains, long-term declines in the annual discharge from shrinking mid-latitude glaciers, and coastal vulnerability to rising sea-levels. In a submission to the United Nations Framework Convention on Climate Change, the FAO (2011d) warned that slow-onset climate changes threaten to have 'potentially catastrophic' impacts on agriculture across the Global South, especially from the middle of the twenty-first century onwards (FAO 2011d). The danger to agriculture from elevated heat and aridity is especially worrisome in the semi-arid tropics, which are home to more than one-fifth of humanity and already possess very high levels of poverty, hunger, and malnourishment, as well as high levels of agriculture-based livelihoods (see Cline 2007, Schmidhuber and Tubiello 2007, IPCC 2007, Nellemann *et al*. 2008, McIntyre *et al*. 2009, FAO 2011c).

The earth is already locked into a significant amount of warming, due to the persistence of GHGs in the atmosphere, the thermal lag of the oceans, and various positive feedbacks like declining ice and albedo already in train, and there are growing fears that the 2°C increase in average temperatures above pre-industrial averages will be breached before 2050 in the absence of immediate, drastic GHG emission reductions, as there is almost no hope that agriculture could widely prosper if average temperatures move beyond this level. These fears are given strength by mounting empirical evidence that many important changes (e.g. sharp declines in Arctic Sea Ice, the Greenland and West Antarctic Ice Sheets, and mid-latitude glaciers) are surpassing upper-end projections from recent climate models, which in turn involve strong positive feedbacks and the danger that non-linear changes will be initiated and the process of change could take on an irreversible momentum (Flannery 2009, Rogelj *et al*. 2011, Joshi *et al*. 2011).

In light of the magnitude and scientific understanding of the risks associated with continuing increases in atmospheric GHG concentrations, it is clear that the precautionary principle should be motivating multilateral and national efforts to

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[11] This also says nothing of the disastrous climatic repercussions that would ensue from more deforestation to expand the land area in cultivation or pasture, namely the huge carbon emissions and lost sequestration capacity.

mitigate the scale of change (Ackerman 2009). The mitigation imperative is marked by grossly unequal per capita atmospheric footprints, as the world's wealthiest industrialized countries possess roughly 15 percent of the world's population and account for nearly half of the world's CO_2 emissions, unevenness which grows further when historic emissions are considered (UNDP 2007). The urgent mitigation challenge is further complicated by surging GHG emissions of industrializing countries like China (which recently overtook the US as the world's largest total emitter), Brazil, and India. Tensions between countries with high per capita emissions and lower but growing per capita emissions have come to dominate multilateral negotiations on climate change, culminating in feeble commitments to GHG emission reduction targets (along with equivocal promises for adaptation financing), a failure which amounts to a 'prescription for a widening gap between the world's haves and have-nots' (UNDP 2007, 167).

Conclusions

In 2007, amidst rising food prices, the former UN Special Rapporteur on the Right to Food described the agrofuel boom as a 'crime against humanity'. That year, roughly 100 million tons of grain (mostly maize) were converted to ethanol, and modest amounts of soybeans and rapeseed were converted to biodiesel (Foer 2009). The same year, almost 10 times as much coarse grain, soy, and rapeseed were used as feed, the products of which were consumed disproportionately in wealthy countries and by wealthier people within industrializing countries. Although this disparity between feed and fuel is closing fast, and it would be hard to overstate the economic, social, and environmental implications of the agrofuel boom on a world scale, at the same time it should not overshadow the need to also challenge the older, similarly regressive, and still bigger flows of grains and oilseeds through industrial livestock.

This is especially concerning since the meatification of diets is projected to continue rising unevenly, and since uncritical assumptions about affluence-related dietary aspirations underpin calls for the doubling of world food production. Meatification is thus a key part of the serious misrepresentation that occurs when champions of high-input agriculture portray hunger and future food security as matters of enhanced yield, and by extension matters of more input-intensive approaches and/or continuing genetic modification of seeds and animals. Rather than ratcheting up insufficient yields and production, a much more compelling priority is to urgently ratchet down meat consumption and confront the social and ecological disaster that is industrial livestock production.

As has been emphasized, the great surpluses of cheap food from the industrial grain–oilseed–livestock complex involve an illusion of efficiency, which is defined in terms of high yields and high productivity per farmer. This system has contributed to dramatic dietary changes around the world, generating the unequal meatification of diets that is skewed heavily by affluence, the flipside of which is deep grain import dependence in many poor countries. However, this cheap bounty is also highly unstable, which becomes clear as we appreciate the biophysical problems posed by mechanization and standardization, how these problems get overridden, and how this involves tremendous amounts of land, water, fertilizer, chemicals, fossil energy, toxic runoff, nutrient loading, and GHG emissions – all of which are greatly magnified by the loss of useable nutrition in cycling ever more feed through concentrated livestock and, by the operations of the industrial sites themselves. As the illusion of efficiency begins to crack, the long-term vulnerability associated with tying food security to flows of cheap food over great distances is increasingly coming into focus.

In the short- to medium-term, as the costs of production in the industrial grain–oilseed–livestock complex rise and agrofuel demand grows, the pressure on food prices in world markets could well serve to further empower surplus grain–oilseed–livestock exporters, not only economically but geopolitically, given how import dependence has been constructed over the past half-century. At the same time, the prospect of rising food prices is most daunting for many of the world's poorest countries, especially the LIFDCs, where food (principally grain) imports are an important part of both food security and balance of payment challenges, and which must be faced alongside the great adaptation challenge posed by climate change. In the longer-term, as a major factor contributing to climate change, the course of industrial livestock production poses a threat to the very foundations of world agriculture.

The sizable role of unequal meat consumption in per capita GHG emission disparities ties it to the fraught geopolitics of climate change, in which the world's wealthiest countries and most powerful corporations have been unwilling to confront historic and enduring consumption inequalities and fast-industrializing countries largely refuse confront consumption trajectories, while the world's poorest people face the most immediate and acute threats. Given the repeated failures of multilateral negotiations and most national governments to establish aggressive, binding GHG emission reduction targets, much of the hope for mitigation now resides in the prospect of the climate justice movement gaining enough strength to push policy changes at multiple scales (Tokar 2010, Bond 2010). Reversing the meatification of diets and challenging the industrial grain–oilseed–livestock complex deserves a central place in this movement.

To approach climate change mitigation with the urgency it demands would shake this system of agriculture to its core. The mitigation imperative demands a radical reframing of how efficiency is understood, away from yield and output per worker and towards a much more comprehensive conceptualization where efficiency involves minimizing external inputs, fossil energy, toxic contaminants, and GHG emissions, and enhancing species richness, nutrient cycles, soil formation, carbon sequestration, and net productivity per land area – that is, as the aggregated output of multiple crops, and not only that of a single high-yielding one. Accordingly, low-input, biodiverse, and more labour intensive small farms nested within more localized food economies would emerge as being far superior to industrial monocultures tied to global flows of inputs and outputs. Indeed, there is is much empirical evidence to support the contention that such farms can indeed 'feed the world' while, in the terms of Vía Campesina, helping 'cool the planet' by reducing emissions and enhancing sequestration capacity (Badgely *et al.* 2007, Snapp *et al.* 2010, Altieri and Toledo 2011, Martinez-Alier 2011). From this perspective, the de-industrialization of livestock production and the de-coupling of huge flows of grains and oilseeds from livestock production can be seen as a fundamental basis for rebuilding more equitable and sustainable agricultural systems, opening space on high-quality arable land yet still shrinking the overall land given to agriculture. Ultimately, this priority also means problematizing dietary aspirations. While the meatification of diets has long been held as a goal and measure of development and a marker of class ascension, it should instead be understood as a vector of global inequality, environmental degradation, and climate injustice.

References

Ackerman, F. 2009. *Can we afford the future? The economics of a warming world*. London: Zed Books.

Altieri, M.A. 1995. *Agroecology: The science of sustainable agriculture*. Boulder, CO: Westview.

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment*, 74(1/3), 19–31.

Altieri, M.A. and V.M. Toledo. 2011. The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty and empowering peasants. *Journal of Peasant Studies*, 38(3), 587–612.

Badgley, C., J. Moghtader, E. Quintero, E. Zakem, M.J. Chappell, K. Avilés-Vásquez, A. Samulon and I. Perfecto. 2007. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems*, 22(2), 86–108.

Barreto, P., C. Souza, R. Nogueron, A. Anderson and R. Salomao. 2006. *Human pressure on the Brazilian Amazon forests*. Belem: World Resources Institute.

Bello, W. 2009. *The food wars*. London: Verso.

Berlan, J.-P. 1991. The historical roots of the present agricultural crisis. *In*: W.H. Friedland, L. Busch, F.H. Buttel and A.P. Rudy, eds. *Towards a new political economy of agriculture*. Boulder, CO: Westview Press, pp. 115–136.

Blas, J. and G. Meyer. 2012. UN urges US to cut ethanol production. *Financial Times*, August 9. Available from: http://www.ft.com/intl/cms/s/0/8808b144-e240-11e1-8e9d-00144feab49a.html#axzz27nBos4QJ [Accessed 10 September 2012].

Bond, P. 2010. Climate justice politics across space and scale. *Human Geography*, 3(2), 49–62.

Boyd, W. 2001. Making meat: Science, technology, and American poultry production. *Technology and Culture*, 42(4), 631–664.

Boyd, W. and M. Watts. 1997. Agro-industrial just-in-time: The chicken industry and postwar American capitalism. *In*: D. Goodman and M. Watts, eds. *Globalising food: Agrarian questions and global restructuring*. New York: Routledge, pp. 192–224.

Brown, L.R. 2009. Could food shortages bring down civilization? *Scientific American*, 300(5), 50–57.

Brown, L.R. 2011. The new geopolitics of food. *Foreign Policy*, May/June. Available from: http://www.foreignpolicy.com/articles/2011/04/25/the_new_geopolitics_of_food [Accessed 3 December 2011].

Cline, W.R. 2007. *Global warming and agriculture: Impact estimates by country*. Washington: Center for Global Development.

Cordell, D. and S. White. 2011. Peak phosphorus: Clarifying the key issues of a vigorous debate about long-term phosphorus security. *Sustainability*, 3(10), 2027–2049.

Cordell, D., J. Dangert and S. White. 2009. The story of phosphorus: Global food security and food for thought. *Global Environmental Change*, 19, 292–305.

D'Silva, J. and J. Webster, eds. 2010. *The meat crisis: Developing more sustainable production and consumption*. London: Earthscan.

De Schutter, O. 2010. Report submitted by the Special Rapporteur on the right to food, to the Human Rights Council, Sixteenth session, Agenda item 3. Available from: http://www.srfood.org/images/stories/pdf/officialreports/20110308_a-hrc-16-49_agroecology_en.pdf [Accessed 1 November 2009].

Flannery, T. 2009. *Now or never: Why we need to act now to achieve a sustainable future*. Toronto: HarperCollins.

Foer, J.S. 2009. *Eating animals*. New York: Little, Brown and Company.

Food and Agriculture Organization (FAO). 2009a. *The state of food insecurity in the world 2009: Economic crises – impacts and lessons learned*. Rome: FAO.

Food and Agriculture Organization (FAO). 2009b. *The state of food and agriculture – livestock in the balance*. Rome: FAO.

Food and Agriculture Organization (FAO) 2011a. *Looking ahead in world food and agriculture: Perspectives to 2050*. Rome: FAO.

Food and Agriculture Organization (FAO). 2011b. *World livestock 2011 – livestock in food security*. Rome: FAO.

Food and Agriculture Organization (FAO). 2011c. *Climate change, water, and food security*. Rome: FAO.

Food and Agriculture Organization (FAO). 2011d. Climate change and food security in the context of the Cancun agreements. Submission by the FAO to the 14th session of the AWG-LCA, in accordance with paragraph 1 of the Bali Action Plan. Rome: FAO.

Food and Agriculture Organization Statistics Division (FAOSTAT). 2012. *Production and resource STAT calculators (livestock primary)*. Rome: FAO. Available from: http://faostat.fao.org/site/569/default.aspx#ancor [Accessed June 2012].

Friedmann, H. 1990. The origins of third world food dependence. *In*: H. Bernstein, B. Crow, M. Mackintosh and C. Martin, eds. *The food question: Profits versus people*. New York: Monthly Review Press, pp. 13–31.

Friedmann, H. 1993. The political economy of food: A global crisis. *New Left Review*, I(197), 29–57.

Friedmann, H. 2005. Feeding the empire: The pathologies of globalized agriculture. *In*: L. Panitch and C. Leys, eds. *The empire reloaded: Socialist register*. New York: Monthly Review Press, pp. 124–143.

Giampietro, M. and K. Mayumi. 2009. *The biofuel delusion: The fallacy of large scale agro-biofuels production*. London: Earthscan.

Gilland, B. 2002. World population and food supply: Can food production keep pace with population growth in the next half-century? *Food Policy*, 27(1), 47–63.

Goodland, R. 1997. Environmental sustainability in agriculture: Diet matters. *Ecological Economics*, 23(3), 189–200.

Graziano da Silva, J. 2012. The US must take biofuel action to prevent a food crisis. *Financial Times*. August 9. Available from: http://www.ft.com/intl/cms/s/0/85a36b26-e22a-11e1-b3ff-00144feab49a.html#axzz280bYFdHg [Accessed 10 September 2012].

Headey, D. and S. Fan. 2010. *Reflections on the global food crisis: How did it happen? How has it hurt? And how can we prevent the next one?*. Washington: International Food Policy Research Institute.

Hecht, S. B. 2005. Soybeans, development and conservation on the Amazon Frontier. *Development and Change*, 36(2), 375–404.

Hertel, T.W., M.B. Burke, and D.B. Lobell. 2010. The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change*, 20(4), 577–585.

Houtart, F. 2010. *Agrofuels: Big profits, ruined lives and ecological destruction*. London: Pluto.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate change 2007: The physical science basis, contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

International Energy Agency (IEA). 2009. New energy realities – world energy outlook calls for global energy revolution despite economic crisis. Paris, IEA press release. Available from: http://www.iea.org/textbase/press/pressdetail.asp?press_rel_id=275 [Accessed 7 September 2009]

Jarosz, L. 2009. Energy, climate change, meat and markets: Mapping the coordinates of the current world food crisis. *Geography Compass*, 3(6), 2065–2083.

Joshi, M., E. Hawkins, R. Sutton, J. Lowe and D. Frame. 2011. Projections of when temperature change will exceed 2°C above pre-industrial levels. *Nature Climate Change*, 1(10), 407–412.

Kimbrell, A. ed. 2002. *The fatal harvest reader: The tragedy of industrial agriculture*. Washington: Island Press.

Lappe, F.M. 1991/1971. *Diet for a small planet*. New York: Ballantine.

Leitzmann, C. 2003. Nutrition ecology: The contribution of vegetarian diets. *American Journal of Clinical Nutrition*, 78(3), 657–659.

Martinez-Alier, J. 2011. The EROI of agriculture and its use by the Via Campesina. *Journal of Peasant Studies*, 38(1), 145–160.

Mason, J. and P. Singer. 1990/1980. *Animal factories*. New York: Harmony Books.

McIntyre, B.D., H.R. Herren, J. Wakhungu and R.T. Watson, eds. 2009. *International assessment of agricultural knowledge, science and technology for development: Synthesis report*. Washington: Island Press.

McMichael, A.J., J.W. Powles, C.D. Butler and R. Uauy. 2007. Food, livestock production, energy, climate change, and health. *The Lancet*, 370, 1253–1263.

Midkiff, K. 2004. *The meat you eat: How corporate farming has endangered America's food supply*. New York: St Martin's Press.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and human well-being: Synthesis*. Washington: Island Press.

Montgomery, D.R. 2008. *Dirt: The erosion of civilizations*. Berkeley: University of California Press.

Moore, J.W. 2010. The end of the road? Agricultural revolutions in the capitalist world-ecology, 1450–2010. *Journal of Agrarian Change*, 10(3), 389–413.

Nellemann, C., M., MacDevette, T. Manders, B. Eickhout, B. Svihus, A.G. Prins and B.P. Kaltenborn, eds. 2009. *The environmental food crisis: The environment's role in averting future food crises*. United Nations Environment Programme, GRID-Arendal. Norway: Birkeland Trykkeri AS.

Neumann, K., P.H. Verburg, E. Stehfest and C. Muller. 2010. The yield gap of global grain production: A spatial analysis. *Agricultural Systems*, 103(5), 316–326.

Nierenberg, D. 2005. *Happier meals: Rethinking the global meat industry*. Washington: WorldWatch Paper #171.

Paarlberg, R. 2010. *Food politics: What everyone needs to know*. New York: Oxford University Press.

Pew Commission on Industrial Farm Production. 2008. *Putting meat on the table: Industrial farm animal production in America*. Washington: The Pew Charitable Trusts and The John Hopkins Bloomberg School of Public Health.

Pimentel, D. 2006. Soil erosion: A food and environmental threat. *Environment, Development and Sustainability*, 8(1), 119–137.

Pimentel, D. and M. Pimentel. 2003. Sustainability of meat-based and plant-based diets and the environment. *American Journal of Clinical Nutrition*, 78(3), 6605–6635.

Righelato, R. and D.V. Spracklen. 2007. Carbon mitigation by biofuels or by saving and restoring forests? *Science*, 319(5840), 902.

Robbins, P. 2003. *Stolen fruit: The tropical commodities disaster*. London: Zed Books.

Robinson, T.P., P.K. Thornton, G. Franceschini, R.L. Kruska, F. Chiozza, A. Notenbaert, G. Cecchi, M. Herrero, M. Epprecht, S. Fritz, L. You, G. Conchedda and L. See. 2011. *Global livestock production systems*. Rome: FAO and ILRI.

Rogelj, J., W. Hare, J. Lowe, D. P. van Vuuren, K. Riahi, B. Matthews, T. Hanaoka, K. Jiang and M. Meinshausen. 2011. Emission pathways consistent with a 2°C global temperature limit. *Nature Climate Change*, 1(10), 413–418.

Rosset, P. 2006. *Food is different: Why we must get the WTO out of agriculture*. London: Zed Books.

Schindler, D.W. and J.R. Vallentyne. 2008. *The algal bowl: Overfertilization of the world's freshwaters and estuaries*. Edmonton: The University of Alberta Press.

Schmidhuber, J. and F.N. Tubiello. 2007. Global food security under climate change. *Proceedings of the National Academy of Sciences of the United States*, 104(50), 19,703–19,708.

Shiva, V. 2008. *Soil not oil. Environmental justice in an age of climate crisis*. Boston: South End Press.

Snapp, S.S., M.J. Blackie, R.A. Gilbert, R. Bezner-Kerr and G.Y. Kanyama-Phiri. 2010. Biodiversity can support a greener revolution in Africa. *Proceedings of the National Academy of Sciences*, 107(48), 20840–20,845.

Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales and C. de Haan. 2006. *Livestock's long shadow: Environmental issues and options*. Rome: FAO.

Tilman, D., C. Balzer, J. Hill and B.L. Befort. 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*, 108(50), 20,260–20,264.

Tokar, B. 2010. *Toward climate justice: Perspectives on the climate crisis and social change*. Porsgrunn, Norway: Communalism.

United Nations (UN). 2009. *World economic situation and prospects 2009*. New York: United Nations.

United Nations Development Programme (UNDP). 2007. *Human development report 2007–8: Fighting climate change: Human solidarity in a divided world*. New York: Palgrave Macmillan.

US Department of Agriculture, National Agricultural Statistics Service (USDA NASS). 2008. *The census of agriculture, national agricultural statistics service*. Available from: http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf [Accessed 20 April 2009].

Weis, T. 2007. *The global food economy: The battle for the future of farming*. London: Zed Books.

Weis, T. 2010a. The accelerating biophysical contradictions of industrial capitalist agriculture. *Journal of Agrarian Change*, 10(3), 315–341.

Weis, T. 2010b. The ecological hoofprint and the population bomb of reverse protein factories. *Review*, 33(2/3), 131–152.

White, T. 2000. Diet and the distribution of environmental impact. *Ecological Economics*, 34(1), 145–153.

Winders, B. 2009. *The politics of food supply: US agricultural policy in the world economy*. New Haven: Yale University Press.

Winders, B. and D. Nibert. 2004. Consuming the surplus: Expanding ‘meat’ consumption and animal oppression. *International Journal of Sociology and Social Policy*, 24(9), 76–96.

WorldWatch 2004. Meat: Now, it’s not personal! But like it or not, meat-eating is becoming a problem for everyone on the planet. *WorldWatch Magazine*, 17(4), 12–20.

York, R. and M.H. Gossard. 2004. Cross-national meat and fish consumption: Exploring the effects of modernization and ecological context. *Ecological Economics*, 48(3), 293–303.

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