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MONOCULTURES

A Blight on Human and Planetary Health

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Abstract

Naturally occurring ecosystems are highly complex almost everywhere. Human impact on the environment has, over tens of thousands of years, resulted in their transformation and simplification. The rate at which this has occurred has been accelerating with increases in population size and the development of industrial economies. Much of the impact is the result of food-raising practices, but other human choices regarding land and water use, including mining, forestry and the growth of cities, have also contributed.

The hallmark of the human footprint is monoculture, a result of deliberate choices in agriculture, the raising of animals for meat and dairy, and forestry, but now appearing, as an unintended by-product of human activity, in the oceans and soil. By definition, monoculture represents a decline of species over some particular area. As monoculture has become the widespread norm in food raising, species decline is occurring almost everywhere. There are other quantifiable, mostly detrimental, changes that extend out from monocultures and their impact on the simplification of ecosystems as chains and nets of causes and consequences. These span an array of intentional human behaviours designed to maintain monocultures and unforeseen outcomes for the planet and its inhabitants. Such inputs and outcomes include:

- kidnapping and slavery
- distortions of production systems
- fold changes over time of consumption of foods and nutrients, with impacts on human behaviour and health
- widespread and increasing antibiotic and hormone use
- similar increases in pesticide and herbicide use

- combinations of genetic modification of plants and pesticide use
- thus, selection against beneficial species and for unwanted species: microbial, animal and plant
- soil loss
- soil degradation
- pollution of soil, freshwater, oceans
- habitat destruction
- climate disruption.

It is not yet clear how we can reverse many of these trends, but monoculture is one of the central problems we need to solve in order to slow the decline of planetary and human health.

Introduction

Humans began as gatherer-hunters.[1] At varying times in the past 10–15,000 years and in various parts of the world, we began to domesticate animals and cultivate specific crops (Ponting, 1992). For much of our subsequent history, cultivated grains (sometimes as mixed-crop agriculture, sometimes more extensively planted as a single crop) have provided the majority of human energy intake, often supplemented by hunting, fishing and gathering, as well as by raising domesticated sources of animal protein in the form of eggs and dairy products and, relatively less importantly until quite recently, meat.

The following nutrients are rare in nature: sugar, salt, fat, meat, alcohol. The following sources of mood-altering drugs are similarly rare: tobacco, poppies, coca, marijuana, coffee, tea, cocoa. We have a taste for them all and, because they are rare and thus consumed at a high level infrequently, there have been no deleterious evolutionary consequences. Hence, we have not evolved any natural curbs on their frequent overconsumption. Based on our experience of crop raising, humans increasingly focused on raising these specific crops in more organised fashion. Today, this approach has led us to a high intake of energy-dense food and various combinations of drugs (alcohol has the dubious distinction of being an energy-dense drug). Thus, our response to the rarity of specific nutrients and drugs – once we had established that we did not have

1 The usual designation of hunter gatherers appeals to the Tarzanist fantasies of some commentators, but gathering has almost always been a much more secure source of dietary energy than hunting, across the world and throughout history.

just to gather and hunt – was to cultivate them to keep ourselves in calories and comfort. Our commitment to this approach has led us to more and more intensity in the way we raise our food (and drugs). This is the problem of monoculture.

From Gatherer-Hunters to Industrial Agriculture

The agriculture of settled communities is one of several human strategies aimed at ensuring a regular food supply. It has benefits as well as drawbacks when contrasted with the gatherer-hunter economy. It may be, as Ponting (1992) has suggested, that a population of around four million was all that could be supported by a gatherer-hunter lifestyle. However, there is good evidence that humans contributed to the reduced carrying capacity of the environment by hunting out megafauna over a relatively short period almost everywhere (Rule et al., 2012) – although climate change has also been important, whenever humans appeared in numbers, food animals became scarce, both locally and continent wide (Flannery, 1997, 2001; Lorenzen et al., 2011). This pattern has persisted to the present day. Settling down and raising crops overcomes the problem of the human-induced scarcity of hunted animals. Further, settlements can be established near a secure water supply and defended against animals, nomads, gatherer-hunters, other settled groups and refugees. Such settlements allow food storage, which evens out variations in supply, both seasonal and weather related. Settlement facilitates cooperation and builds communities, although these processes clearly began much earlier with gatherer-hunters. It allows specialisation and leisure for increased development of art and science (although, again, surely among the greatest human art is the work of gatherer-hunters at Chauvet and Lascaux, France, and other palaeolithic art galleries (Valladas et al., 2001; Balter, 2008)). Essentially, of course, settlement provides food security – dependent, always, on climate and weather.

The drawbacks of the peasant agricultural economy include a decline in the variety of food consumed; deficiency diseases, both because of this decline and because of the potential for crop failure; increased crowding compared to the gatherer-hunter lifestyle, with increasing risk of epidemic and endemic infectious diseases. There is always the possibility of multi-year crop failure and consequent starvation; a settled community finds it harder to move again and recapture the nomadic gatherer-hunter lifestyle. The Greenland cattle-raising community refused to acknowledge that the climate was worsening and that the growing season was shortening; this had disastrous consequences for the settlers (Gribbin and Gribbin, 1990). Nonetheless, some humans have been able to show appropriate flexibility: the north American (Iowa) Indians of Mill

Creek adapted to worsening climatic conditions by reverting to hunting and gathering as primary strategies after being successful grain farmers (Gribbin and Gribbin, 1990).

Much of subsequent human history has involved: small decentralised local populations; animal-assisted agriculture; a relatively 'inefficient' human labour-intensive production system, often with storage and loss problems, a low crop yield compared with what is now achieved with industrial farming and less intensive land use. Many of these aspects of inefficiency, however, are much closer to the behaviours needed to maintain long-term ecologic balance. The food production system, moreover, was efficient enough to ensure the growth of cities, especially in Europe, even if some of the impetus was provided by a decades-long recovery following huge human die-off as a result of epidemic disease (Tuchman, 1979). The food production system was highly dependent on weather, rainfall and temperature. Food distribution was via small-scale local markets, or even family/village self-contained production. Distances over which food was traded were small (though trade in more durable goods was over much longer distances). Finally, this economy also involved a distribution of wealth and power (e.g. peasant farmers and warrior/landowners in Europe) that ensured food security for the few and more tenuous survival for the many.

Initially, humans made transitions to something approaching monocultures with crops like sugarcane (see below). However, as the power of the ruling classes ensured a better transition from feudal states to a capitalist economy for the aristocrats and landowners than peasant farmers, much of the shared land, common land, 'wasteland' and woodland was seized and enclosed (nowhere more obviously than in England (Hoskins, 1970)). This allowed grain crops to be grown over larger areas, with some benefits from the resulting production efficiency but substantial loss of livelihood for the landless workers and smallholders, who, to survive, migrated to the cities, providing cheap labour for the Industrial Revolution.

Thus, we moved from a gatherer-hunter economy to peasant agriculture, with its mixed-cropping subsistence and focus on immediate needs for energy (mostly grain) supplemented by small quantities of animal protein. We became increasingly urban with an industrialised agriculture. By the 20th century, all was different: there had been a massive decrease in human labour and a corresponding increase in fossil fuel use to supply energy – the success of the Industrial Revolution in creating wealth in cities was increasingly used as a blueprint for agriculture. This energy use, along with the Haber–Bosch process of fixing atmospheric nitrogen to make inorganic fertilisers, allowed a vast increase in production capacity and was an essential driver of the 20th-century population rise (Smil, 1999). These changes were further augmented by the development of pesticides and herbicides, and from the middle of the

20th century, the intensive development (and restriction) of crop species; this 'Green Revolution' further increased food production capacity. The resulting industrialised agriculture is conducted over large areas, with reduced human labour input and no animals to provide either energy or fertilisers. It supplies large centralised populations and, with major changes in transport, allows extensive trade over large distances. The power and centralisation of control of production have increased (albeit with corporations having taken the place of warrior landowners), with many workers in the system (needed for harvest, particularly) living marginal lives on low wages and no job security. Much of this system, however, does not function according to neoliberal market models, but is highly subsidised by governments, further distorting the distribution of power and wealth.

It has been estimated that 30–50 per cent (1.2–2 billion tonnes (Bt)) of all human food produced is never consumed (Institution of Mechanical Engineers, 2013). Another estimate suggests that total production is around 19 megajoules (MJ) per person per day, but what is available for human consumption is around 8 MJ per person per day (McIntyre et al., 2008b). Yet today, we are trapped by the manufactured, but widespread, belief that we need to increase food production to supply a massive and still increasing human population. What is actually needed is an integrated food distribution and security system that is not driven by profit and protection but by human need and human-scale solutions (Nierenberg et al., 2011). Indeed, as Tudge (2013) has noted, industrial monocultures – the farming practices supposed to be feeding the world – in reality provide less than one-third of the world's food. Twenty per cent comes from fishing, hunting and back gardens, and half comes from small, mixed traditional farms (McIntyre et al., 2008a).

Our capacity for food production stretches the boundaries of what is possible for the planet. Industrialised agriculture, incarnated as extensive monoculture, is regarded as the norm for supplying the world's food. That, itself, is a false claim, but its deleterious consequences – to the planet and human health – abound. Three examples, sugar, meat and cereals, follow.

Sugar

Sugarcane, a grass initially from South Asia, provided a local luxury for much of human history. It began to be cultivated intensively in the 19th century, as a crop that has remained labour-intensive in many parts of the world to this day. In order to supply that labour, cane plantation owners turned to the African slave trade from the 18th century (Richardson, 1987), and to its marginally more benign South Pacific descendant in the 19th (Price and Baker, 1976). Almost zero-cost labour to produce a lucrative crop meant huge profits as a result of growing sales to an increasingly addicted population (Rönnbäck, 2007).

Sugar consumption in the UK around 1700 was less than 2 kg per year from multiple sources (Mintz, 1985); by 1990, in Australia, it was more than 40 kg per year (Espinel and Innes-Hughes, 2010) – a more than 20-fold increase, with comparable rises throughout the industrialised world. In the USA, sugar in soft drinks alone now accounts for about 13 per cent of daily dietary energy intake among teenagers (Jacobson, 2005).

The industry began (like tobacco) with kidnapping, slavery and casual murder to acquire the relevant workforce (Solow, 1987). As with agricultural workers in many parts of the world, sugarcane cutters often remain members of an informal, 'casual' labour force on low wages, with few rights or benefits. Even in high-income countries, cane cutting was a brutally hard seasonal job in hot conditions until largely replaced by mechanisation.

The deliberate human inputs into sugarcane production over the past 150 years have included 'clearing' of land for plantations; an early (1935) attempt at biologic control of pests (Phillips et al., 2006); use of conventional pesticides and herbicides; fertiliser use; and mechanisation and fossil fuel use.

Some of the unplanned outcomes for human health (see Table 13.1) include high consumption of sugar itself (Monteiro et al., 2011), leading to obesity, diabetes, caries, etc (Jacobson, 2005; Lustig et al., 2012); high alcohol consumption leading to alcoholism, trauma, violence and chronic disease, including cancer (Pelucchi et al., 2011); loss of jobs requiring physical labour, resulting in declining employment and declining physical activity in the population, but also reduction of workplace accidents and increased longevity.

Table 13.1 Sugar monoculture: Deliberate human inputs and unplanned outcomes.

Planned products	Planned inputs	Unplanned outcomes (human health)	Unplanned outcomes (planetary health)
Sugar		Obesity, diabetes, caries	
Alcohol		Alcoholism, trauma, violence, chronic disease, including cancer;	
	Sugar plantations		Habitat loss, decline in diversity
	Kidnapping and slavery (18th and 19th century)	Reduced longevity	Shifts in human populations
	Biologic pest control		Unchecked cane toads (*Bufo marinus*)
	Mechanization and fossil fuel use	Declining physical activity Declining employment Reduction of workplace accidents and increased longevity	Climate disruption
	Pesticides		Disruption of chemical cues, including those involved in reproduction
	Herbicides		Mangrove dieback Deleterious consequences for coral ecosystems
	Fertilizers		Decline in coral reef health particularly the rise in Crown of Thorns starfish (*Acanthaster planci*)

Source: Author's work.

Some of the unplanned outcomes for planetary health (Table 13.1) include habitat loss and decline in diversity (Gomiero et al., 2011); unchecked, rapidly evolving cane toads (*Bufo marinus*), which now have a range of more than 1 million square kilometres (Phillips et al., 2006); contributions to climate disruption as a result of industrialisation and mechanisation of agriculture (Rockström et al., 2009); decline in coral reef ecosystem health, particularly the rise in crown-of-thorns starfish (*Acanthaster planci*) as a result of fertiliser use and nutrient run-off (Brodie et al., 2005); mangrove dieback (Duke et al., 2005) and consequences for coral ecosystems (Lewis et al., 2009) as a result of herbicide exposure; disruption of chemical cues, including those involved in reproduction (Luccio-Camelo and Prins, 2011) in a variety of organisms by pesticides, which are widespread in coral ecosystems (Johnson and Ebert, 2000).

Meat

Humans have a long history of meat consumption, although our closest primate relatives are vegetarian (*Gorilla gorilla*) or low, but clearly not zero, meat consumers (*Pan troglodytes* and *Pan paniscus*) (Nishida and Uehara, 1983; Stanford, 1996; Hofreiter et al., 2010). Further, there is good evidence that some of our hominin cousins (*Australopithecus bahrelghazali*, *Paranthropus robustus* and *Australopithecus sediba*) were largely plant eaters (Balter et al., 2012; Henry et al., 2012a; Lee-Thorp et al., 2012). Evidence from contemporary gatherer-hunters suggests that the majority of their dietary energy is derived from plants. Nonetheless, by the end of the last ice age, some 10–12,000 years ago, humans demonstrated both extensive hunting skills and a taste for meat (Smil, 2002), devastating the megafauna on all continents except Africa, including Australia, as well as on islands (Flannery, 1997, 1999, 2001; Rule et al., 2012).

With the transition to a pastoral lifestyle, humans began to raise animals for meat and milk, in settlements or as seasonal nomads (these usually also raised crops) or fully nomadic (Ponting, 1992). In this economy, animals were raised on land not used for crops. As with the gatherer-hunter economy, the majority of dietary energy is derived from plant foods.[2] This land use ensured that the best soil was used for raising plant foods. It also allowed other land to be cleared of scrubby plants and improved by fertilisation with animal manure. Further, crop stubble could be used as animal food and, again, the fields fertilised and then allowed to lie fallow. The practices of crop rotation, mixed cropping and raising animals on more marginal land were central features of human agriculture across the world, although the crops and animals varied widely. Indeed, these practices still persist in many parts of the world. However, in those areas where agriculture has been replaced by industrial farming, much has changed: crops are not rotated; land does not lie fallow; animals have become a dominant 'crop'; and land of any quality, including land hacked out of pristine rainforest, is used. Livestock now occupy 30 per cent of the Earth's entire land surface, mostly permanent pasture but including 33 per cent of the global arable land, which is dedicated to producing feed. In Latin America, about 70 per cent of former Amazon forest has been turned over to grazing (Steinfeld et al., 2006); animals are irrelevant to soil fertility (indeed CAFOs[3] ensure that the soil and groundwater are damaged by excretions); artificial fertilisers and consequent soil degradation are common; animals have often ceased to feed on grass and consume far more energy-dense food in the form of grains and legumes.

2 There were and are clearly some exceptions to this, particularly among nomadic pastoralists and among humans who live at northern extremes but, even there, plant foods are important, including those harvested from the stomach contents of herbivores.

3 Concentrated animal feeding operations, now used extensively for cattle in the USA and for pigs and chickens in many parts of the world.

This approach to animal raising increases greatly the availability of meat (refrigeration and freezing have also been important). This, in turn, has increased demand for meat, such that the current level of consumption in rich countries is unprecedented in human history. Meat consumption in traditional agricultural societies was rarely higher than 5–10 kg a year; in most subsistence peasant societies of the Old World, meat was eaten once a week or less, with relatively larger amounts consumed only during festive occasions. (Smil, 2002). Meat consumption in Australia, the USA and New Zealand is now around 110–120 kg per year (a 12- to 24-fold increase). India, in contrast, has a per capita consumption around 4 kg a year (Espinel and Innes-Hughes, 2010) (see also FAOSTAT: faostat3.fao.org/home/index.html#COMPARE).

There are unplanned consequences (see Table 13.2) of this shift from raising animal protein as a modest supplement to a plant-based diet to providing as much as 15–20 per cent of total energy (in India, the proportion is less than 1 per cent). For human health, those consequences include elevated disease – obesity, cardiovascular disease, diabetes and cancer – as a result of high consumption of meat and fat (Linos et al., 2008); accelerated human sexual development either as a result of meat and fat consumption itself (Rogers et al., 2010) or possibly arising from low-dose, naturally occurring or exogenous growth-promoting hormones in meat (Courant et al., 2008); extensive antibiotic resistance among organisms that affect humans, e.g. *Salmonella*, *Escherichia coli*, following antibiotic use to promote animal growth (Health Council of the Netherlands, 2011) – about 80 per cent of all antibiotics sold in the USA are used in animals (Food and Drug Administration, 2013). There has been a reduction of available human food (and consequent hunger for those reliant on grain and subsistence agriculture) as cattle are fed energy-dense grains and legumes: more than 97 per cent of the soymeal produced globally is fed to livestock (Steinfeld et al., 2006). There are higher risks of bacterially infected meat from animals raised in the highly crowded settings of feedlots and CAFOs (Price et al., 2007; also www.cdc.gov/salmonella/typhimurium-groundbeef/010512/index.html); this leads to recommendations to consume heavily cooked meat, a source of colorectal carcinogens (Potter, 1999); crowding also increases the risk of *Salmonella*-infected eggs. Pig CAFOs act as a point source and 'mixing vessel' for recombination of epidemic influenza strains (Gray and Kayali, 2009; Forgie et al., 2011) and mixing animal vaccines has been shown, on at least one occasion, to lead to the emergence of a virulent field strain as a result of the recombination of two attenuated strains in the setting of a factory farm (Lee et al., 2012). Current feeding practices have also ensured the ill health of the animals themselves. Some of the resultant diseases are zoonoses: bovine spongiform encephalopathy was a direct result of recycling infected animal parts as food to obligate herbivores (Matthews, 1990).

Table 13.2 Meat monoculture: Deliberate human inputs and unplanned outcomes.

Planned products	Planned inputs	Unplanned outcomes (human health)	Unplanned outcomes (planetary health)
Meat and eggs **Animal fat** **Overcooked meat**		Chronic disease, including cardiovascular disease, obesity, diabetes, cancer, etc.	
	Clearing of prairie, woodland, etc, for cattle		Habitat loss, decline in biodiversity
	Hard-footed animals on fragile topsoil		Topsoil loss
	Rainforest destruction		Habitat loss, decline in biodiversity, climate disruption
	Water use		Aquifer depletion
	Total biomass of cattle four times that of humans		Methane production leading to climate disruption
	Hormone use to stimulate growth, e.g. cattle, fowl	Effects on human sexual development	Environmental/ reproductive effects, e.g. on fish
	Antibiotic use to stimulate growth, e.g. pigs	Antibiotic resistance among organisms that affect humans, e.g. *Salmonella, Escherichia coli*	
	Switch to grain feeding	Reduction of human food supply	
	Concentrated animal feeding operations (CAFOs)	*E. coli*-infected meat supply *Salmonella*-infected eggs Influenza point source Vaccine recombination leading to virulent field strain from two attenuated strains	Groundwater pollution
	Culls to protect cattle against tuberculosis, e.g. of bison, badgers		Decline in biodiversity

Source: Author's work.

Some of the unplanned outcomes for environmental and planetary health (Table 13.2) include habitat loss and decline in diversity (some decline in biodiversity is quite deliberate, with the intensive culling of badgers (Steinfeld et al., 2006) and bison from specific regions, with the dubious goal of protecting cattle from tuberculosis); rainforest destruction (Steinfeld et al., 2006);

topsoil loss, particularly in Australia (Fanning, 1999); disruption of reproduction in fish and amphibians following exposure to environmentally relevant concentrations of steroid hormones (Vandenberg et al., 2012); the depletion of aquifers (Steinfeld et al., 2006) – it takes more than 110,000 litres of water to produce 1 kg of meat protein (Mekonnen and Hoekstra, 2010). The production of methane is now estimated to be 65 million tonnes (Mt) per year from beef and dairy cattle enteric rumination, another 20 Mt from other ruminants and a further 18 Mt from animal manure, accounting for 37 per cent of anthropogenic methane (with 23 times the global warming potential of CO_2) and for 65 per cent of anthropogenic nitrous oxide (almost 300 times the potential of CO_2), the great majority from manure. Livestock are also responsible for groundwater pollution, as well as 64 per cent of anthropogenic ammonia emissions, which contribute significantly to acid rain and acidification of ecosystems (Steinfeld et al., 2006). There are major contributions to global climate disruption from the combination of rainforest destruction and the production of greenhouse gases: at 18 per cent of all greenhouse gases, the livestock sector generates more than transport (Steinfeld et al., 2006).

In a world of stalling cereal production, grain is now being used to make biofuels and to feed cattle. Meat and dairy animals now account for about 20 per cent of the total terrestrial animal biomass – about four times that of humans (Steinfeld et al., 2006). Accordingly, world meat production and consumption is continuing to increase, but with marked inequalities and new attitudes to food; whereas, once, plant foods were staples and meat was the garnish, now, increasingly, meat is seen as essential and plants much less so. Nonetheless, of course, grain remains the major source of human dietary energy that it became with the establishment of settled farming communities. What has changed is that cereals, too, are a central part of how we raise food as monocultures.

Cereals

The features of medieval European (and probably continuously from much earlier) village farming included shared fields and shared labour; mixed crops; rotation to allow fallowing and grazing; and (obviously) the use of animals for ploughing. This pattern has been particularly well characterised by Hoskins for England (Hoskins, 1970), who also chronicled the changes to the mid-20th century.

Enclosures meant more private property and much clearer title to land; loss of woodland; loss of shared labour; loss of common land. It also meant marginalising smallholders, and often deprivation of their livelihood. John Clare (1793-1864), the working class romantic poet, put it like this in *The Fallen Elm*:

It grows the cant term of enslaving tools
To wrong another by the name of right;
Thus came enclosure – ruin was its guide,
But freedom's cottage soon was thrust aside
And workhouse prisons raised upon the site.
E'en nature's dwellings far away from men,
The common heath, became the spoiler's prey
The rabbit had not where to make his den
And labour's only cow was drove away.
No matter – wrong was right and right was wrong,
And freedom's bawl was sanction to the song…

In freedom's name the little that is mine.
And there are knaves that brawl for better laws
And cant of tyranny in stronger power
Who glut their vile unsatiated maws
And freedom's birthright from the weak devour.

The loss of woodland meant loss of biodiversity. Hedgerows, which from then increasingly marked field boundaries, still provided some cover for birds and beneficial insects.

Since then, this pattern (which we think of as quintessentially defining the English countryside (Hoskins, 1970)) has given way to increasing 'prairie-isation'; this pattern is not like the boundary-free fields that had existed earlier, particularly because a great deal of the woodland and wild land disappeared with enclosures. Over the past 50 years or so, the hedgerows have been eliminated and mechanised farming has been facilitated – both ploughing and harvesting; short-term efficiency has thereby been improved and immediate financial costs reduced. However, much else has deteriorated, much has been lost.

Other farming systems, for example in Australia and North America, already used very large areas and were extensively mechanised relatively quickly. However, much was lost in the USA as the real biodiversity of the prairie succumbed to the plough – elegiacally chronicled by Aldo Leopold (1949).

Rice, the predominant staple in 17 countries in Asia and the Pacific, as well as in countries in the Americas and Africa, provides 20 per cent of the world's dietary energy supply, about the same proportion as wheat and about four times that of maize (FAO, 2012). Grown largely in necessarily flat, flooded fields and extensively on smaller holdings, rice is less amenable both to very large single areas under cultivation and to mechanisation (Van den Berg et al., 2007). However, there are increasing approaches to mechanisation, both for planting (Dixit et al., 2007) and harvesting (Horio, 2009).

The major benefit of widespread cereal cultivation, rather than mixed crops, crop rotation and small-scale animal/plant raising, is the ability to secure a more predictable supply of dietary energy. Indeed, the cereal monocultures of Australia and North America, particularly, allow an extensive export trade; other former importers have become exporters following the 'Green Revolution'. The major planned inputs in cereal monocultures include not only the extensive 'clearing' of land – woodland, prairie and rainforest – but also considerable increases in mechanisation and the use of fertilisers, herbicides and pesticides.

Unplanned consequences for human health (see Table 13.3) include the fact that maize and other cereals are now used to provide not only whole food but also increasing numbers of food fractions unrecognisable by our ancestors. These include high-fructose corn syrup (HFCS), which is widely used as an energy-dense sweetener in many manufactured foods. Many of the metabolic consequences of high exposure to fructose are like those of alcohol (Lustig, 2010). HFCS also provides empty calories, increasing the incidence of chronic disease, including obesity and diabetes (see above). Grain is also used to produce alcohol, high consumption of which also elevates chronic diseases, including cancer and alcoholism, as well as contributing extensively to trauma and violence. The use of human food to make biofuel, alcohol and high-value food fractions also means reduced food availability in marginal economies (Mitchell, 2008). Although the 'Green Revolution' produced multiple problems (Shiva, 1991; Hazell, 2009), it did increase crop yield substantially. In contrast, the use of genetically modified (GM) varieties shows little or no improvement in yield, and indeed, often a lower yield than conventional strains (Gurian-Sherman, 2009). Declining physical activity, as well as declining employment, follow from widespread mechanisation of farming, although the reduction in the number of workers who spend their lives in very hard physical labour has contributed to increased longevity in some settings. Use of specific pesticides and herbicides has increased risk of lymphoma among the highly exposed (Kogevinas et al., 1997); there may be a less detectable burden across the population.

Table 13.3 Cereal monoculture: Deliberate human inputs and unplanned outcomes.

Planned products	Planned inputs	Unplanned outcomes (human health)	Unplanned outcomes (planetary health)
Cereals Derived food fractions (including white flour, corn syrup)		Obesity, diabetes, caries, etc.	
Alcohol		Alcoholism, trauma, violence, chronic disease, including cancer	
Biofuels		Reduced food availability in marginal economies	
	Cereal fields, cleared from prairie, forest, etc, or concentrated by enclosures and later by elimination of hedgerows (UK)		Habitat loss, decline in diversity
	Mechanisation and fossil fuel use	Declining physical activity Declining employment Increased longevity	Climate disruption
	Pesticides, particularly neonicotinoids		Colony collapse disorder among honeybees (*Apis mellifera*, etc.) Loss of other beneficial insects and bird-eating insects Development of pesticide resistance in unwanted species, which leads, in turn, to increased use of pesticides (vicious circle)
	Herbicides	Lymphoma	Herbicide resistance among unwanted plants, leading to greater herbicide use (vicious circle) leading to 'need' for development of genetically modified (GM) strains
Genetically modified (GM) strains		No improvement in yield; often a lower yield than conventional strains	Loss of beneficial insects, e.g. from insertion of *Bacillus thuringiensis* genes Increased herbicide use on GM herbicide-resistant maize further increased as herbicide resistance develops among unwanted plants
	Fertilisers		Soil degradation

Source: Author's work.

Some of the unplanned outcomes for environmental and planetary health (Table 13.3) include increasing habitat loss and decline in diversity as a consequence of land clearing (Chamberlain et al., 2000); fresh water loss and aquifer depletion – in 2000, agriculture accounted for 70 per cent of the world's fresh water consumption (Steinfeld et al., 2006); greenhouse gases and climate disruption that follows from mechanisation of farming and fossil fuel (Potsdam Institute for Climate Impact Research and Climate Analytics, 2012). Pesticides (particularly neonicotinoids) have a major influence on marked declines in honeybees (*Apis mellifera*) and other pollinators (Gill et al., 2012; Henry et al., 2012b; Whitehorn et al., 2012). Use of pesticides ensures both loss of other beneficial insects and bird-eating insects and the development of pesticide resistance in unwanted species (Heckel, 2012), which leads, in turn, to increased use of pesticides (vicious circle). Herbicide resistance among unwanted plants leads to greater herbicide use (another vicious circle) and, together with insecticide resistance among unwanted species, has led to justifications for the development of GM strains that are resistant to herbicides or that carry genes for pesticides (e.g. insertion of *Bacillus thuringiensis* genes). However, this has increased biocide use, which, in turn, has accelerated herbicide resistance among unwanted species in an ever-tightening vicious circle (Benbrook, 2012). There are now more than 200 herbicide-resistant species across the world (www.weedscience.org/summary/home.aspx). GM insecticide-producing crops also contribute to the loss of beneficial insects (Hilbeck et al., 2012). There are more contested data that suggest that use of GM cereals and the associated high use of glyphosate may have consequences for mammalian health as well (European Food Safety Authority, 2012; Séralini et al., 2012).

Other Monocultures

Other monocultures include those consequent upon wide-scale use of forests of pine, eucalyptus and other trees. Clearing for such forests means soil loss, acidification and salinisation; reduced biodiversity; species and habitat loss; and reduced water availability for nearby communities (Cannell, 1999; Jackson et al., 2005; Karumbidza and Menne, 2011). Large-scale fishing operations look a lot like strip-mining of the oceans (Puig et al., 2012) and have produced the emergence of untoward unplanned monocultures (Acuña et al., 2011; Condon et al., 2011). Increasing reliance on small numbers of plant species means loss of varieties and loss of genetic variation. This is particularly concerning for important human crops like bananas (D'Hont et al., 2012) and tomatoes (The Tomato Genome Consortium, 2012).

A Counterfactual World

It is possible to ask what the world might be like if we had not developed industrialised food production. Certainly, the fixing of nitrogen was a key step in improving productivity (Smil, 2000), which contributed, in turn, to rapid changes in human population size. Now, of course, we could not feed the world's population without inorganic fertilisers (Smil, 1999), but it is equally true that we would not have had the growth of population without the food the fertilisers made possible. Could we have lowered infant mortality rates and improved longevity without markedly increasing the size of the human population (itself now the greatest burden on planetary health and a cause of the Anthropocene mass extinctions)? Could we have somehow made a transition to a world where life was not nasty, brutish and short for most? It seems as though, if industrialised agriculture supplied only one-third of all food, we might have been able to do it – but not within the structure of current-day oligopoly capitalism and massive protectionism for large food-producing corporations. Now, it has become hard to picture a way back – or forward.

Events and Trends

Humans have become good at rapid disaster management. However, we are very poor at slow disaster management, including increasingly hostile environmental conditions and climate disruption. Although the short-term advantages of monocultures are definable and include the provision of adequate food for a large proportion of the seven billion humans now alive (benefits for the many), as well as power and control of much of that food supply by a small number of individuals and corporations (benefits for the few), there are obvious and growing problems that we need to solve quickly if we are not to live in a world dominated by catastrophic collapse across the environment. We are now facing, not necessarily in order of importance or imminence: the accelerating disappearance of birds, which are key insectivores, and thus, the increasing appearance of insects in plague proportions (consequences include declining crop yields and increasing insect-borne diseases); the accelerating disappearance of bees, which are not relevant for cereals and legumes but, of about 100 crops that provide 90 per cent of the world's food, 71 are pollinated by bees (United Nations Environment Programme (UNEP), 2010); out-of-control herbicide-resistant weeds, competing for food-producing land; accelerating loss of rainforest; increasing climate disruption with effects on coastal lands, temperatures, water supplies, rainfall and weather patterns; growing loss of biodiversity; increasing use of human food for cattle; more frequent crop failure as a result of degraded soil, lack of new arable land and falling water supplies;

perhaps GM crop failure as a result of unforeseen weaknesses in the newly cobbled genomes – and, as a result of these, increasing food deprivation for the poor but increasing obesity, diabetes, coronary heart disease and cancer for the rich.

Although much of this could flow just from increasing human numbers and our neglect and abuse of the only planet we have (Jenkins, 2003), energy-profligate, herbicide- and pesticide-addicted monoculture is making these problems that much more severe, that much closer at hand and that much more urgently in need of attention.

One of the reviewers of this chapter properly noted that I needed to acknowledge that all was not dismal and that there were alternatives (both goals and practices) to the road we were on, involving, for instance improved distribution (Nierenberg et al., 2011); scrutiny and labelling of GM food (European Commission Directorate General for Health and Consumers, 2010) (although evidence of effective field control is scant (Bauer-Panskus et al., 2013) and expenditure on misinformation is extensive – see the Proposition 522 fight in Washington, USA (www.organicconsumers.org/essays/did-anti-gmo-movement-really-lose-washington); alternative pest-control systems (Lewis et al., 1997; Chandler et al., 2011); ecologic agricultural management (Buck and Scherr, 2011; La Via Campesina, 2013); and the food sovereignty movement (Claeys, 2012; La Via Campesina, 2013). I acknowledge, applaud and support these activities (among other things, I grow organic food and keep bees), but I remain sceptical of long-term beneficial outcomes when these trends are arrayed against the power of sociopathic international capitalism.

Charles Darwin begins the final paragraph of *Origin of Species* with the following:

> It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. (Darwin, 1883)

He then enumerates those laws, which include growth and reproduction, inheritance, variability, 'a ratio of Increase so high as to lead to a Struggle for Life', natural selection, divergence of character and extinction. We seem, increasingly, to find ways to disrupt, mock or intensify the impact of these laws. We do so at growing peril to ourselves and to the planet.

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