CAT GSE

Sustainability and Adaptation

Ecosystems Module November 2015

FOOD AND FOOD SECURITY

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NOTES

This lecture is intended as general introduction to the basic data and statistics you will need to understand food systems in the world and in the UK. However, from the perspective of Sustainability and Adaptation, the question of food security often becomes a focus, hence the emphasis on it here.

There are two aspects to the matter of food security, with somewhat different characters.

One is the ‘traditional’ global problem of whether there is enough food to feed the world, and prospects for the future. It is a question that goes back to Malthus’ celebrated *Essay* of 1798 (Malthus, 1997) and runs on into modern times (e.g., Paddock and Paddock, 1967). Today it is considered to be a question largely about poor people in developing countries, and it is worth remembering that regional famines still do happen.

The other area of interest is the UK itself, and this is relatively new. Ever since the repeal of the corn laws in 1846 it has been assumed that, as a wealthy country, Britain could always buy whatever food it wanted on the world market, and that for reasons of ‘comparative advantage’ this was economically a good idea. Eventually the UK imported 60% of its food. This proved rather awkward during the interruptions of supply caused by the second world war, and in the postwar period there were strenuous efforts to increase national self sufficiency in basic foods.

The return of political stability and the operation of market forces eroded this impulse, and now Britain imports nearly half its food. But recently there have been doubts, occasioned principally by the prospect of ‘peak oil’ and possible disruptions brought about by climate change. These could affect the UK as a whole, or possibly sub-populations if there is some kind of infrastructure breakdown, a possibility that is actively discussed.

The lecture will address these two aspects of the topic in turn, but they share a recurrent theme, that food security is strongly associated with **diets and the agricultural product mix**. If there is a textbook for the lecture, it would be Colin Tudge’s *Feeding People is Easy* (Tudge, 2007). His thesis is that indeed it *is* easy if there is not too much livestock in the mix, but since the universal trend is towards *more* livestock, the problem is getting more difficult, with obvious implications for food security.

BACKGROUND DATA AND PRINCIPLES

Basics of nutrition

Food security is not only about total quantities, but getting adequate amounts of three different nutritional classes. We need **energy foods** in relatively large quantities, **structural materials** in lower quantities, and a variety of **vitamins and minerals** in very small quantities. It does not matter much where these come from, and traditional diets vary enormously, from (for example) an all-meat diet to a no-meat diet.

Evolutionary pressures

Humans have evolved to deal with fairly concentrated sources of food, as opposed to, say gorillas, living mostly on leaves, who have to eat enormous quantities to get enough actual nourishment. One of the mechanisms driving the search for concentrated sources appears to be specific evolutionary ‘hungers’ for sugar, oil and the salty/savoury taste known as ‘umami’, supplied generously by meat. In most natural environments these food types are scarce, so even exaggerated efforts to procure them cannot lead to having ‘too much’. In modern food systems however, all these are available cheaply in limitless quantities, and the result is a wide range of food-related pathologies including obesity, diabetes, heart disease, some cancers, bowel disorders and so on (Cordain *et al*., 2005).

It is a widely-noted paradox that in some parts of the world people suffer from the effects of too much food, while in others they suffer from too little.

The rise of agriculture

Agriculture generates more reliable human-type food per unit area than wild nature, so it seems like a clear gain in terms of food security. However, wherever agriculture has historically appeared, it has led to a rise in population to match, so in the end little is gained in terms of food per head. But once established, the larger population cannot be maintained by pre-agricultural systems and there is no way ‘back’ (Diamond, 1987).

Agrarian societies concentrate on starchy crops, which make up most of the diet, greatly facilitated by cooking. Surplus production leads to stratification of society, and those at the top have better, more varied diets, including more sugar, oils and meat.

Concentration on certain crops can be vulnerable to weather extremes, pests and diseases and lead to periodic famines. Something of the kind could be seen in the Irish famine as late as 1847. At the extreme, agrarian cultures can experience chronic failure in food supplies, leading to total collapse (Tainter, 2003; Diamond, 2005).

Modern agriculture

In pre-modern societies most people are farmers, but with shifting agricultural technology fewer and fewer people are needed to produce food for everyone else. Eventually this gets down to a few percent of the population. In Britain it is about 1.5%. At the same time food gets cheaper relative to incomes. From spending more than 70% of household income on food, it goes down to about 10% in a fully modern society like the UK. Much of this expenditure is on ‘luxury’ items that are not strictly necessary for optimum health. Probably less that 5% of average household income is necessary for the basic foods, and this is a remarkable achievement for modern societies. Cheap and abundant food, and 100% food security, is taken as basic and unalterable fact.

Dietary shifts

In a modern society food is cheap, but includes a large proportion of materials that satisfy the evolutionary ‘hungers’ without necessarily providing the necessary basic food types. These are both demanded by a large section of the population and vigorously marketed by the food industry. The result is an unmistakeable statistical shift towards eating too much food of the wrong sort for optimum health (Beddington *et al*., 2012). Fats and sugar might be bad for health but they are not particularly damaging to the environment; nor do they take up excessive amounts of land.

In contrast, the trend towards consuming more meat and dairy products potentially has much more serious implication for food security. The underlying reason for this is the loss of efficiency in moving up a ‘trophic pyramid’ (Odum, 1971). Each step in a food chain is usually accompanied by a loss of energy greater than 90%, and in the case of agriculture this translates into much larger areas required to produce livestock products rather than crops for direct consumption. In a globalised food market, rich consumers can have whatever they want. They can easily pay for large areas of land, domestically or overseas, to produce the forage and feed crops for the livestock. And this is what tends to happen. Local and subsistence crops are displaced. Prices go up. People go hungry. Giving some idea of the scale of this effect, Nelleman *et al*. remark, “The loss of calories by feeding the cereals to animals instead of using the cereals directly as human food represents the annual calorie need for more than 3.5 billion people”. (Nelleman *et al*., 2009)

In the most general terms, total world food production *is* keeping up with a growing total population (Beddington *et al*., 2012) although this is being undermined by dietary shifts. Much of the apparent increase is destined for animal food, so is ‘worth’ only a fraction of its recorded output in terms of nutrition and food security.

Effects of the food system on ecosystem services

In 2009 Rockström and colleagues produced a widely-applied framework for assessing environmental sustainability, in the form of global trends measured against ‘nine planetary boundaries’ (Rockström *et al*., 2009). Two of these are familiar as climate change and the associated acidification of the oceans, and are driven principally by energy production. Another four, however are driven principally by developments in food, agriculture and land use, principally a shift towards higher consumption of livestock products (Pelletier and Tyedmers, 2010).

These changes have strong effects on the natural environment, with longer-term implications for global food security via the loss of ‘free’ ecosystem services (Millennium Ecosystem Assessment, 2005). It is an uncomfortable fact that misguided attempts to ‘improve’ food supply are among the greatest threats to food security.

Global trade in food.

While the world contains a large number of subsistence farmers, their numbers are declining. Increasingly, food supply is a high-tech, professional business and almost certain to remain so barring a massive collapse of international order. Although most countries supply most of their own food, a large quantity of food products is traded across national boundaries, often moving very long distances. Component products are processed, re-combined and shipped further distances.

Are these ‘food miles’ a problem for food security? It is sometimes thought so, because remote supplies can be diverted or interrupted and are not under the control of the consuming community. But in a globalised world, food is produced and processed where it is most efficient to do so, with transport a minor element of the total system. This is probably more ‘secure’ than relying simply on local production, although there is no reason why the two should not exist side by side.

This view presumes the existence of well-functioning states and economic systems, but as the present century progresses this presumption might not always hold. Greater security might start to switch back to national, or even local, supply.

Mineral nitrogen and other fertilisers

‘Fertilisation’ of soil is necessary for food crops, to replace nutrients inevitably lost by harvesting. This replacement is usually done by chemical fertilisers, mostly containing the elements nitrogen, phosphorus and potassium. Nitrogen is needed in the largest quantities, and it is normally manufactured by the Haber-Bosch process that extracts nitrogen from the air and turns it into solid forms available to plants. It has been argued that the growth of the world population in the 20th century was largely based on the extra food that could be produced through Haber-Bosch nitrogen (Smil, 1997) and is now completely dependent on it.

This presents a difficulty for both sustainability and security, because the total flow of nitrogen is now much greater than the natural flows, with all manner of profound ecological effects. Nitrogen flows constitute one of Rockström *et al*.’s planetary boundaries, and the present values far exceed the boundary (Vitousek *et al*., 1997; Schlesinger *et al*., 1997).

The dilemma can be simply stated: reduce mineral nitrogen use→lower yields→, widespread starvation. Maintain mineral nitrogen use→growing damage to ecosystem services→lower yields→widespread starvation. There’s an essay here!

Comment on drivers of changing diet and product mixes

The food industry as a whole would no doubt claim merely to be satisfying market demand. If there is a problem of sustainability or security, it is therefore *consumers* that should alter their demands. An alternative view is that to a large extent demand is shaped by producers and retailers through advertising, marketing, selective pricing and quasi-monopolistic powers (Lang and Heasman, 2004). Therefore *they* are the agents that need to change. As competitive enterprises however, such agents cannot be expected to change unilaterally: they must be obliged to do so by collective regulation, usually imposed by national governments or international trade bodies, or by consumer action.

In thinking about food policy, we need to consider both elements of demand-pull and supply-push. Neither can be neglected.

Geo-political aspects

Generally speaking, agricultural production is far more advanced and productive in wealthy, developed countries, mostly in the higher latitudes of the northern hemisphere. As a broad generalisation, they could feed themselves from their own resources without recourse to the poorer ‘South’. Ironically, as global temperatures rise, the ‘North’ will often experience agricultural benefits, at least for a while (Smith, 2010; Beddington *et al*., 2012).

The ‘South’ is likely to experience much greater difficulties, for numerous reasons, possibly getting worse as the climate shifts. Problems of food security are likely to be exacerbated by the economic power of the North using resources from the South for production of luxury foods, at the expense of staples for human consumption.

“Collapse”

Historically, numerous agricultural civilisation have ‘collapsed’ in the sense of losing their stratified structure and abandoning their urban centres (Diamond, 2005). Usually the final collapse is brought about by a lack of food, but this itself is often the result of unanticipated climate change (especially extended drought) or the steady erosion of basic resources such as soils, water supplies, forest cover and so on.

In his provocative book *Collapse*, Jared Diamond speculated that modern societies were broadly subject to the same constraints and could also suffer collapses, at least locally. In a globalised modern world is this really plausible? Undeniably we do have much better technology, distribution systems, and means of predicting likely problems.

If there are indeed localised collapses, how are they likely to be distributed? An interesting study by Rogers *et al*. (2011) compares egalitarian and stratified societies facing severe stresses, and finds that in some cases stratified societies managed to keep the core structures intact by ‘sequestering mortality in the lower classes’. In other words, the rich survived while the poor died, principally through starvation. If there are to be selective collapses (Randers, 2012) we might well find this is the default pattern (Orlov, 2008).

SOME OTHER ISSUES

Indirect effects of food policies

This has already been touched on in various ways, but essentially in a globalised world, economic power can have dramatic remote effects. A demand will tend to find the cheapest route for meeting it, and the cheapest resources are usually in developing countries, partly because local consumers cannot compete, and partly because ‘natural’ resources such as forests are not defended. The level of such effects can be remarkably high. In the case of indirect GHG emissions Audsley *et al*. (2010) calculated that indirect effects accounted for 48% of the land required for UK food.

With respect to food security, it is often potentially productive land that is remotely appropriated, competing with local crops. The strongest effects are from soybean production, and oil for biofuels.

Soybean production

Soybeans are extremely productive in terms of oil and protein, and could easily provide abundant sustainable supplies of these products for pretty well everyone (Pelletier and Tyedmans, 2012). But 90% of soybean production is used for animal or fish feed and biodiesel fuel, and demand for these items drives further expansion of soya production, frequently leading to deforestation (Morton et al., 2006). Soya production is not intrinsically bad, but simply used for the wrong purposes.

Biofuels

‘Biofuels’ are generally understood to be liquid fuels that substitute fairly directly for existing motor fuels. They are meant to be a contribution to decarbonising the transport sector and a certain percentage is mandated in all motor fuels by the EU. The intentions are good!

Biofuels are derived from plant seeds, either as oils, or as starch that is then fermented to ethanol. Seeds are only a small part of a total crop, so yields are relatively poor per unit area, and when other energy inputs are taken into account the energy (and carbon) gain is only around 50%.

The potential for rich Europe to command land for inefficient fuels that could be used for other purposes, should be obvious. Although Europe produces most of its own biodiesel fuel, this too displaces valuable arable land that could be used for other purposes.

These conflicts can be expressed in terms of opportunity costs (Righelato and Spracklen, 2007), and have the same ‘shape’ as opportunity costs for soya/livestock (Berlin and Uhlin, 2004).

Food Waste

There is always ‘waste’ in the food system, from crops not fully harvested, to rejected parts in processing, preparation waste in the home, and plate waste. Modern economies tend to waste more in the home; developing societies waste more in production and distribution. This reflects both the value of food and the efficiency of the infrastructure.

It should be mathematically obvious that for a given demand, if less is wasted, less land and other resources are required to meet the demand. It is more damaging to waste ‘high intensity’ foods like meat, dairy, oils.

Up to 30% of UK food is ‘wasted’ along the food chain, and it would probably be possible to halve this, and improve nutrient recovery from the rest. In traditional cultures food scraps were routinely fed to livestock, particularly pigs and poultry, giving an effectively ‘free’ source of animal protein. This has become unusual in modern societies, and in fact is illegal in the UK, although increasingly food waste is composted domestically or collected for composting.

Fish

Wild marine fish are a significant part of many diets around the world, but the limits have finally been reached. Total catches of wild fish have not increased since about 1990 (FAO, 2010). One quarter to one third of this total is used as fish meal to feed livestock and farmed fish (*ibid*.). Fishing pressure has substantially affected the ecology and population-structures of many fish populations, and some have collapsed entirely (Hutchings and Reynolds, 2004). Commercial sea-fishing is a classic example of a ‘Tragedy of the Commons’ (Hardin, 1968) where each individual boat or fleet tries to maximise its catch without regard to the ultimate collective effect.

Demand continues to increase however, and the shortfall has been made up by farmed fish, fed largely on ocean fish and soybean meal. This is not rational or efficient, and is yet another case of a potential threat to food security brought about by attempts to secure a superior diet. Ocean fish can be farmed sustainably, and can provide a modest high-protein supplement to a modern diet; but in the long term, not more than this.

THE UNITED KINGDOM FOOD SYSTEM

The UK produces about half its own food, particularly grains, meat and dairy products. Imports include a wide variety of tropical foods such as beverages, bananas, sugar, and ‘European’ foods such as wine, oil and olives. It imports most of its fruit and vegetables. A large proportion of imports are not consumer foods but animal feeds such as soya meal.

The system assumes a global food market and low transport costs, and items are simply sourced at the lowest price. Retail prices are set largely by supermarkets through which 80% of household food is obtained.

There is a striking difference between the production of food on UK farms, and the food industry ‘after the farm gate’. Although it occupies over 70% of the land, farming accounts for only 0.6% of the GDP, employs 1.5% of the workforce, and uses 1.6% of the energy supply. As an economic sector it is very small. After the farm gate however, the food industry accounts for 13% of the GDP, employs 12.5% of the workforce and uses 14% of the energy (DEFRA, 2011).

We eat almost nothing straight from the farm. It is elaborately transported, transformed, preserved and packaged. It is hard to imagine a complex, largely urban, modern society where something of the kind does not take place, and barring total societal collapse, we must assume that the basic structure is here to stay.

The question of national self-sufficiency

Although Britain does not currently produce all its own food, several writers have asked whether it could, in principle, do so. Mellanby (1975) asked *Can Britain Feed Itself?* And his answer was that it clearly could, although it would need modest reductions of land-hungry livestock. The issue was revisited by Fairlie (2007) who considered a number of different scenarios, clearly showing that low-livestock scenarios delivered more food on less land. Audsley *et al*. (2009) calculated that with a very low livestock scenario, the UK could produce all its own food and leave more than half the agricultural area ‘unused’ for other purposes. This is the approach that has been taken up by the Zero Carbon Britain project (CAT, 2010). An Ecological Footprint analysis of the land required to grow the UK’s food represented by a map of the UK suggests that the whole of ‘England and Wales’ are taken up by livestock products, Scotland and Northern Ireland the rest (Best Foot Forward , n.d.) .

Food security in the UK

Under present circumstances it is difficult to imagine serious threats to the UK’s food security in terms of quantities, although there are already problems with food *quality* in low-income households (Food Ethics Council, 2010). It is sometimes thought that ‘peak oil’ might be a threat to food security if farmers cannot run machinery. However, energy for the agricultural sector is less than 2% of the national energy demand, and would certainly be given priority if there were doubts about food supplies.

It is worth remembering that the British Isles did experience a major famine, in Ireland in 1840s, and we can still ask, could it happen again? It does not seem quite plausible. Short of the kinds of collapse scenarios discussed above, it is hard to imagine that farmers will simply stop farming, or that the processing and distribution systems will stop functioning.

It is probably worth remarking at this point that malnourishment of various kinds can arise through cultural forces. Popular journalism, and documentary programmes on radio and TV, is rich in accounts of illnesses of very various kinds, both acute and chronic, brought about by poor dietary choices. In some circumstances this might go as far as ‘starvation in the midst of plenty’ simply because those items regarded as acceptable foods are not available or are simply too expensive.

A basic healthy diet is not expensive by modern standards, but would not be regarded as palatable, or as real food, in some households, who feel compelled by custom, habit, peer norms, commercial pressures and limited information to purchase only specific sorts of foods. It is possible to imagine some effects of (say) a carbon tax that would increase the cost of domestic energy and of processed foods, leading to severe conflicts of choice for some households.

More broadly, we can envisage ‘worst case situations’ brought about by combinations of political, economic and environmental forces in the next few decades. It is difficult to assess how likely these might be, and how much effort should be made to prepare for them. The most likely effects of the collision of population growth and rising aspirations with environmental constraints –long predicted – is of recurrent famines in the global ‘South’, prompting questions of whether the UK should actually become net food exporter to make good food shortfalls elsewhere.

Zero-Carbon Britain 2030

The remainder of the lecture is a brief explanation of the land use aspect of CAT’s decarbonisation scenarios for 2030 (CAT, 2010, 2013). Such scenarios have the difficult task of envisaging a very low carbon UK economy while maintaining all necessary services, including energy and food supplies. It turns out that decarbonising the energy system is relatively straightforward, but doing the same for the food and land systems less so.

In 2010 the Land Use sub-scenario of ZCB2030 was given the following tasks:

* Reduce emissions from all land-based sectors by 80%
* Provide sufficient carbon sinks to offset all residual emissions from the whole economy (67 million tonnes of CO2e)
* Provide storable fuels for load balancing and transport (75 million tonnes of biomass materials)
* Provide an abundant and balanced diet for the expected population of 2030 without reliance on imports.

In the revised 2013 scenario, the requirement for sinks was reduced to around 50 MtCO2e, allowing more flexible choices for their provision: more trees, a lower level of dedicated biomass crops such as miscanthus, and more ‘natural’ in-situ carbon sequestration .

The central process is a switch in the use of grazing land. Perennial forage grasses are largely replaced by perennial biomass crops. This necessarily reduces the grazing herd, mostly cattle and sheep, and this itself reduces national emissions by 5-10%. Does it however, damage food security? Paradoxically perhaps, the answer is ‘no’, because the reduction of grazing livestock reduces the area of arable land required to provide their supplementary feed. This land can now be used much more efficiently to produce a greater quantity of food for direct human consumption. The level of livestock production is thought to be close to the ‘default livestock’ level proposed by Fairlie (2010), following Elferink *et al*. (2008).

In the scenario the UK is 80% self-sufficient in all foods, and 100% in essentials. This is likely to improve food security in the event of a breakdown of overseas supplies, but might damage it in the event of a specific breakdown of UK production. It is worth reminding ourselves that trade is usually a positive factor in food security (Sumner, 2000). These conclusions can be assessed and critiqued by examination of the original spreadsheets. The UK food systems is fairly easily modelled at a crude level of detail.

If the scenario demonstrates food adequacy, does it in fact provide a healthy diet? Diets are partly a personal matter, but it is becoming clear that typical modern diets are far from optimal. What is optimal? The Barilla Centre (Poli, 2010) has analysed a large number of so-called ‘food pyramids’ ranking food types in order of quantities, and reached the conclusion that *the health-ranking rather closely matches the environmental ranking*.

This is a remarkable result, supported by further work by Laura Blake (Blake, 2013).

If the carbon emissions of various diets are plotted against nutritional quality (judged in terms of contemporary food systems) there is a clear correlation between lower emissions and greater health. This correlation is even stronger if the energy system is decarbonised.

Growing Your Own

Is ‘growing our own’ likely to make a serious difference to food security? I am personally an enthusiast, and in a long series of data recording I found that a small urban garden could eventually displace 25% of total household spending on food. This is a substantial fraction, but if food is really short, it’s calories and proteins we need rather than fruit and vegetables. Farmers are very good at producing calories and proteins abundantly and cheaply, so inevitably farmers rather than gardeners will be the main guarantors of national food security.

The ZCB2030 scenarios also diminished indirect threats to food security by reducing impact on biodiversity, biomass appropriation, water consumption, and excess nitrogen.

That all these benign effects could flow from a single approach might seem surprising. But the arguments and evidence appear straightforward and have never been successfully challenged. Criticism of the scenarios is based on the on the fact that, although they are physically plausible, they are politically impossible. Or are they? A chance for some essay or thesis work here!

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