9

Regenerating the earth system, working with climate

Any viable future paradigm must meet mitigation and adaptation criteria. In fact this requirement should be seen not as a constraint, but rather as a responsibility – *and therefore freedom* – to think radically, outside the box. Although issues addressed in this chapter may seem at times technical, there is always a political undercurrent: this has to do with the relationship between *decoupling* development from emissions and *delinking* from capital accumulation circuits (as notably expressed in food value chains), as well as with a whole range of issues around citizen science, open-source, and generally the fact that transition must be a mass movement.

Plants as solar power stations

There is a rhythm in the earth system, whereby the carbon cycle is regulated by seasonal fluctuations in photosynthesis: NASA's Orbiting Carbon Observatory-2 (OCO-2) spotted a 'spring drawdown', 'a portrait of a dynamic, living planet. Between mid-May and mid-July 2015, OCO-2 saw a dramatic reduction in the abundance of atmospheric carbon dioxide across the northern hemisphere, as plants on land sprang to life and began rapidly absorbing carbon dioxide from the air to form new leaves, stems and roots.' (NASA Jet Propulsion Laboratory, 2015).

Photosynthesis uses solar energy to take carbon out of the atmosphere to build the plant and, in so doing, nature has evolved a solution to an extremely difficult problem. In quantum theory, a particle can behave as a wave, permitting it to explore multiple pathways simultaneously and, if only we could harness this, there would be unlimited potential. For example, quantum computers could explore all solutions to a problem at once. In practice, however, this is difficult to achieve. The problem is one we could perhaps represent as a contradiction between complexity and the ability to maintain quantum effects. Complexity enables a huge activity of self-organisation, 'messy' in a good sense, all of which involves heat and motion whose effect would tend to knock out quantum coherence. This is why most quantum experiments are conducted at extremely low temperatures, an example being today's D-Wave quantum computer which, cooled to a fraction above absolute zero (minus 273.15° C), is sometimes called the coldest spot in the universe! Plants face a similar problem to quantum computers (Institute of Photonic Sciences, 2013), but have solved this to near 100 per cent efficiency. When a photon of sunlight hits a magnesium atom in the chlorophyll, it dislodges an excited electron which is unstable, and the challenge is to get it to the reaction centre (the 'battery' where plants store energy) before the energy is lost. This is achieved by the particle exploring simultaneously all possible routes, and 'This wavelike characteristic of the energy transfer within the photosynthetic complex can explain its extreme efficiency, in that it allows the complexes to sample vast areas of phase space to find the most efficient path' (Engel, et al., 2007, p.782). However, it needs to maintain coherence while negotiating the 'chlorophyll forest' and this is done through a kind of rhythm internal to the plant (which has been detected in spinach for example): a 'beating' whereby coherence is maintained in a series of pulses on a scale of trillionths of a second (Al-Khalili and McFadden, 2014).

So in this sense plants are the most efficient solar power stations imaginable, and growing food can be seen as an important part of solar transition.

The role of feedbacks in plant-climate interaction

Farming is related to earth-system regulation as both cause and effect: influenced *by* climate, and at the same time impacting upon it.

With any such two-way cause-and-effect relationship, we encounter what are known in systems jargon as feedbacks. 'Positive feedback', which in everyday speech may imply something good, in systems theory often has a threatening tone because it describes any process where the output is also an input and could cause a runaway loop: as in the screeching when a microphone picks up sound from its own speakers and feeds it back into the amplifier.

The worst positive feedback would be if melting polar ice reduces the earth's albedo (whiteness), thus reflecting away less solar heat and therefore further warming the earth, melting more ice and so on. Avoiding this tipping point (threshold) is the mitigation issue. On the other hand, with some regime-shifts (state-shifts) discussed in Chapter 4, thresholds have already passed and it is too late to stop them: this is the adaptation issue. Food and farming are central to both.

What complicates it is that *negative* feedbacks could counteract climate change to some extent. There are two ways this could happen:

[1] as temperatures rise with global warming, additional heat increases growth, thus absorbing carbon;
[2] since there is more CO_2 around, this could have a similar effect, since carbon is the stuff of plants. Such a development could be good for two reasons:

    (a) negative feedback might be the earth's way of returning to a self-regulating balance;
    (b) more specifically, since food supply benefits from lusher growth, a food productivity gain in temperate regions might outweigh a loss (to drought, for example) at the tropics.

Drawing on recent research, what we can say is that we should definitely not pin too much hope on [1]: temperature increase cuts both ways, reducing growth as much as stimulating it. With respect to [2] on the other hand, recent research (Lu, et al., 2016) and, more specifically, a major study drawing on satellite data (Zhu, et al., 2016), suggests that CO_2 does indeed increase growth. Taking one particular case, simulations suggests that if Tibetan native grasslands are restored, their growth, stimulated by climate change, will mitigate the latter since the cooling effect of evapotranspiration outweighs loss of albedo (Shen, et al., 2015).

Thus (a) may be partly true in the sense that Gaia tries to function as a self-healing system, and this should be an incentive for us to make greater efforts to keep our side of the bargain. However, it is crucial that we don't rely on (b), i.e. some hypothetical climate-induced stimulus to food production. It has already been established that, following an initial increase of yield, this has tailed off and declined (Lobell and Field, 2007). Long-term predictions further emphasise the simple fact that, even if warmth increases at temperate latitudes, light does not! (Mora, et al., 2015). Furthermore, in the case of China, pollution (itself partly resulting from soil erosion) has hampered photosynthesis (Lin Changgui, et al., 2015), which would have the effect of reducing crop yields. The Intergovernmental Panel on Climate Change is therefore categorical: 'Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts (high confidence)' (IPCC, 2014, p.7). To this we can add a remarkable recent finding: increased growth may actually be accompanied by loss of *quality*, since plants respond to higher CO_2 by building proportionally more carbohydrate relative to protein, thus accentuating twin problems of obesity and nutrient deficiency (Ziska, et al., 2016).

While it remains true that anything green should absorb carbon – which is also one argument for greening the city – in reality it is not quite that simple because, in fact, the *way* we grow things is decisive and, if we do it wrong, greenhouse gas (GHG) emission from depleted soils will more than cancel out the absorption effect. A key reason is the bad interaction between nitrogen and carbon in the mainstream farming paradigm (Zhang, et al., 2013) and, according to latest research, if we include in our calculations methane (CH_4) and nitrous oxide (N_2O) as well as CO_2, a net GHG emission from various human land-uses is revealed (Tian, et al., 2016). This argument takes us yet again to the qualitative issue: the whole question is not how *much* we grow, but *how* we grow.

To address this issue of quality, we must understand the critical role played by soil ecosystems, both aboveground and belowground. It seems that, in the multi-loop linkage entwining biodiversity, farming and climate, a key element is how plant residues are consumed. Thus, the good (negative) feedback of increased warmth/CO_2 stimulating plant growth tends to be neutralised by a bad (positive) feedback in the form of enhanced microbial decomposition of this very same growth (van Groenigen, et al., 2014). But, and this is crucial, this bad effect could in turn be negated by the grazing of invertebrates within the soil system, who gobble up vegetable matter *before* it has decomposed, there being an interesting analogy with the aboveground grazing by large animals in limiting warming-induced changes in arctic ecosystems (Crowther, et al., 2015). The issue, therefore, is for our farming and land-management practices to operate in harmony with these natural feedbacks and the ecosystems which convey them.

There is a kind of earth-system balance involved here but, to understand it more deeply, let us revisit the subtle dialectics of 'equilibrium'.

In a thermodynamic sense, the essence of life is to be *not* in equilibrium with your environment (Prigogine and Stengers, 1984). The simplest organism must exploit a kind of 'gradient' between itself and its surroundings, allowing it to extract energy (Le Page, 2016b) and, similarly, earth exists as a living planet by keeping itself *distinct from* its surroundings (space) and by extracting energy from the sun, which is later dissipated (with higher entropy) into space (c.f. Penrose, 2010). The whole point is the internal structures – i.e. the complex systems, *built out of* this energy-transfer – which keep earth distinct from an inhospitable thermodynamic equilibrium with space (i.e. death). Recent research speaks of earth as a battery, equipped with energy stocks – within which the store of living biomass is critical (Schramski, et al., 2015). So again we encounter a kind of balance or 'poise' (a fragile one), which must be maintained: that's the good side of equilibrium. The way to achieve this is to implement agroecological practices which maintain and stimulate the beneficial organisms (such as grazing invertebrates) and processes.

Alongside the living biomass, we can also fix carbon in the soil. Soil holds nearly three times as much carbon as vegetation and twice that of the atmosphere (Wang, et al., 2011), and there is scope to increase this carbon content. At the most simplistic level, we could say that this carbon is merely 'removed' (sequestered), which in itself would be good. However, we can take the argument a crucial step further, since carbon also raises fertility (Lal, 2004). This is where the systemic process really becomes interesting. A good kind of positive feedback can occur which takes the following form: carbon in soil → more growth → more carbon taken from the atmosphere and fixed in soil → more growth, etc. This would in turn open up win-win scenarios, whereby we simultaneously feed the world and mitigate climate crisis, building a new order fuelled by the entropy of the old.

Here again, mitigation is not a constraint but an opportunity. Instead of merely minimising *damage* wrought by food-related emissions (food miles, methane emission from cattle, etc. etc.), we can/must set our sights much higher: develop farming as a benign geo-engineering which actively sucks in carbon. Thus, '…carbon dioxide should be regarded not simply as a 'bad' that has to be stored in underground caverns out of harm's way, but that it can be turned into a good that can be used to enhance the wellbeing of the biosphere and humanity' (Girardet and Mendonça, 2009, p.52). If the 'cavern' option (carbon capture and storage) is risky since there is a strong chance it will leak (Penn State, 2016), fixing it in the soil is both reliable and an actual gain. In a recent survey of different CO_2 options, fixation in the soil comes out top (Pierce, 2016), and continuing research backs this (Paustian, et al., 2016). Our principle should therefore be: 'Organic farming can reverse the agriculture ecosystem from a carbon source to a carbon sink' (Science China Press, 2015).

Moreover, the majority (60–70 per cent) of carbon entering the soil can fall into the category known as *recalcitrant*, remaining stable for millennia, which is of course what mitigation requires, and moreover the deeper the carbon, the more stable it is. If we discover how to stimulate this, we will be finding our way back to the indigenous mindset of thinking long-term, escaping the short-term mentality of capital profit-cycles.

There exist several ways to achieve this and, just to give an idea (without being exhaustive), we can mention a few:

[1] Grazing herds. The roots of perennial grasses can draw carbon several metres below the surface. This therefore raises the issue of how managed grasslands can become a fundamental component of climate mitigation. The UN Food and Agriculture Organization (FAO) made a big stir with a publication, *Livestock's Long Shadow* (FAO, 2006), correctly highlighting the unsustainability of the current mainstream meat industry. However, this touched off an interesting debate exploring how – though a radically different approach – livestock could make a beneficial contribution. Within this discussion, a contribution by Simon Fairlie (Fairlie, 2010) had an impact in changing thinking (e.g. Monbiot, 2010). The key point is that grazing animals are central to natural ecosystems, and we can work with this faculty. One approach developed by Zimbabwean environmentalist Allan Savory, involving periods of short intensive grazing, has given rise to both critical and supportive studies (Joseph, et al., 2002; Sanjari, et al., 2008). At least the general principle seems sound: by constantly cropping – and manuring – perennial grasslands, herds activate a 'pump' drawing carbon into the lower reaches of the soil, where it is sequestered.

Other approaches could be complementary to this one, and in some cases be implemented directly in urban, as well as rural, farming.

[2] Dynamic accumulators. These are plants which have a very deep root system (perhaps up to three metres) and draw nutrients from the rocky layer beneath the soil, the most famous being Russian Comfrey (*Symphytum x uplandicum*) Bocking 14, to which we referred in Chapter 3. If we regard our plot as a closed system, then in a high intensity model we would deplete the soil. If, on the other hand, we open it up to the subsoil and lithosphere

below, we can replenish its fertility, which in this case is achieved through a foliar feed made from comfrey leaves which stimulates growth of food crops.

[3] Rockdust. Naturally, the weathering of rock can absorb carbon, safely transforming it into bicarbonate (Taylor, et al., 2015), and this has been adapted artificially by pulverising exposed volcanic rock. The environmental entrepreneurs who commercialise this procedure promote it as a way of simulating 'Earth's natural remineralisation process – 90,000 years of glaciers grinding rocks to fertilise the next stage of evolution.' (SEER Centre, n.d.). The effect, by raising soil fertility, would be another way of kick-starting a carbon pump.

[4] An approach, which in this case leads us directly back to indigenous experience: terra preta (dark earths).

The latter refers to the historic tradition of building recalcitrant carbon deposits in the soil by pre-colonial Native American civilisations (Roach, 2008). Dark-earth sites are so closely associated with these populations that they form one of the main archaeological indicators in locating their settlements (McMichael, et al., 2014), while even today it is possible to observe this practice in action (Schmidt, 2013). It involves smouldering organic waste, and mixing the resultant charcoal with the soil. Such deposits still provide a high fertility over 1,000 years after they were laid down, proving that there is a win-win solution to the twin goals of long-term sequestration and intensive, sustainable food productivity.

The challenge is to rescue this legacy and make it a key element in a new farming paradigm (McHenry, 2009). In its modern form, terra preta is commonly known as 'biochar' (Steiner, 2009). In its academic aspect, the biochar project – involving, as it does, learning from traditional societies while also understanding what was going on in physical and chemical terms – is necessarily interdisciplinary (University of Wageningen, 2014). But crucially, this is not merely academic: biochar is an international social movement, aimed at creating a simple, low-cost and decentralised technology for pyrolysis. The essential point is that this is intrinsically a commons, open-source technology (International Biochar Initiative, n.d.), continuously refined through citizen science. It unites, on the one hand, the wisdom of crowds as an efficient knowledge-producing mechanism (because it harnesses properties of emergence and self-organisation) and, on the other hand, the demand for democratisation of knowledge.

This reinforces the political dimensions addressed in Chapters 6 and 7. It would be too easy to say that the need for systems to be 'far from equilibrium' is just a technical requirement of thermodynamics (governing dissipative relationships with the external environment), while harmony and balance prevail internally. Such an argument is clearly nonsense: what we need is disruptive forces from regions of a system which are less tied to the ruling paradigm. Superficially, this appears merely *reactive* (i.e. an adaptation issue): Thirsk's research (Thirsk, 1997) shows how, in British history, the ruling order is periodically weakened by environmental threats to which it has no response, and this in turn frees up social forces from below to innovate in *solving* the threat. This is already very interesting but we can go further: as the terra preta issue shows, indigenous deep tradition was somehow aware that we *make* our environment, not just respond to it. Today, we can restore this historical thread. The open-source terra preta movement, going beyond mere adaptation into a benign (biomimicked) environment-building, is a sign that this is happening.