Science Progress (2015), 98(4), 403–412

Current Commentary

Permaculture: regenerative – not merely sustainable

CHRISTOPHER J. RHODES

Fresh-lands Environmental Actions, 88 Star Road, Caversham, Berkshire RG4 5BE, UK. E-mail: cjrhodes@fresh-lands.com

Keywords: *permaculture, sustainable, regenerative, techno-fix, green-tech, green business, soil, climate change, earth stewardship, soil, hydrologic cycle*

September 2015 saw the International Permaculture Conference[1], held in London, followed by the Convergence[2], which occupied 6 days at Gilwell Park, on the Essex–London border, where its practitioners gave presentations and workshops on various aspects of permaculture, which is a sustainable design system intended to emulate the principles of living ecosystems. While it has been emphasised[3] that such terms as sustainable development, and sustainable agriculture, are really oxymorons, since neither untrammelled growth nor our present form of industrial food production can be maintained in perpetuity, permaculture[4] has a value-added factor that extends beyond what might be merely maintained or sustained, which is the quality of regeneration. All sustainable solutions are unsustainable over the longer term, if they are not also intrinsically regenerative.

Nature offers the ultimate example of a design that is both sustainable and regenerative, and it is logical to appeal to natural principles for solutions to many of our current problems. This is sometimes taken to mean that we need adopt more "simple" lifestyles, abandoning our technology in the process, but the reality is more complex. Within a broader perspective of regenerative design, permaculture identifies the elements of sustainable living which are harmonious with nature. Discordant practices which lead, *e.g.* to soil erosion[3], fret the environment, and are neither sustainable nor regenerative, but degenerative.

Regenerative *versus* sustainable

That which is sustainable maintains what already exists, but does not restore (eco)systems that have been lost. The word "sustainable" strictly means "self-sustaining" but is often understood, particularly in the media and by the general public, to merely mean "able to last" or "the capacity to endure." This has been represented, humorously, by the example of two men talking together. One asks the other, "How's your marriage going?" To which the other man replies, rather dejectedly, "Well, it's sustainable." The term has also been used to describe materials, products, or processes that are in some degree (probably) less toxic or damaging to the environment than their more usual versions.

Thus, a product containing 80% recycled material might be described as "sustainable", whereas in reality, it is only relatively more sustainable than a version fabricated with no recycled material at all. To be actually sustainable, a product must be made from 100% recycled (and recyclable) material, so that it can, in its entirety, be further recycled. This is seldom the case, and when the energy costs of the processing are also included, there is an inevitable overall "loss", even if "renewable" energy is used, since such energy sources are usually constructed from materials that must themselves be extracted and processed, all with their own attendant energy demands.

Fundamentally, the word "regenerative" means "the capacity to bring into existence again"; hence, if an item or system is regenerative, it has the inherent capacity to bring itself into existence once more. Thus, for "regenerative" to be an accurate description of a product, it must be not only 100% recycled and recyclable, but also improve the environmental conditions at all stages of its manufacture and use: *e.g*. the factory that made it, those businesses and other organisations which used it subsequently, and so on throughout its life-cycle. These improved conditions might include the creation of habitat (including building soil), water purification, and the enhancement of nitrogen- and carbon-fixing processes in the soil, *etc*. Hence, to achieve this for a completely artificial system is a challenge. The size of a system is an important factor on whether or not it is regenerative, with smaller designs more likely to be stable and fulfil the criterion. It is possible to create larger regenerative systems by linking together smaller regenerative "units" so as to provide inputs for multiple human-inclusive-ecological systems.

In principle, a completed object can generate more energy than was used in its own manufacture (emergy, or embodied energy), a good example being a solar panel which over its lifecycle produces more energy than its emergy. However, the energy costs of making the solar panel are large, when all inputs such as the ultra-high-purity silicon are accounted for, and the device can only be regenerated if enough energy is produced, from solar PV, to generate the materials used to make up the solar panel, and to recycle them into a new one. In terms of foods, it can be said that regenerative food is all organic, but not all organic food is regenerative. If the by-product of the food crop is not used as an input for the crops of the following season and if other inputs for the crop did not come from other resources within the farm in which it is grown, the food system is not regenerative, and not necessarily sustainable, *e.g.* if it relies on liquid fuels derived from crude oil, and natural gas, mined phosphate and potash to provide, respectively N, P and K fertilisers.

Permaculture as part of an overall regenerative design system

The familiar phrase, "nature abhors a vacuum" is a postulate attributed[5] to Aristotle, who reasoned that a vacuum cannot exist in nature because any incipient void would be filled by material from the denser surrounding continuum. This may be taken to reflect the intrinsic design mechanism of nature, in which neither a vacuum nor wasted space is allowed, and is breathtakingly effective in marrying form with function. Two of the cornerstone permaculture design principles[6] are that "Each element performs many functions" and "Each important function is supported by many elements". Accordingly, every element is chosen and placed within the design such that it serves as many functions as possible (probably at least three). By virtue of the second principle, the design is "resilient" if critical functions are supported in a number of different ways, and continues to operate should any one element (system) fail. Through the introduction of multiple systems that support each of particular functions in the design, single points of failure (weak links) are avoided, and it is more probable that the overall system will continue working should unplanned circumstances prevail.

The degree of technological innovation by humans is remarkable, but has advanced to the point at which the industrialised lifestyle it has engendered is fretting the basic elements upon which we depend for our existence at the most fundamental level, in particular, soil, water and air. An adjustment to our use of technology is required and indeed, rather than merely reducing our carbon footprint, we need to target our use of fossil fuels to those purposes that must be maintained in the shorter term, while we focus on energy efficiency and developing those technologies that are environmentally positive and regenerative. It is a critical truth that humans are an intrinsic part of nature, but the two are often regarded as if they have separate identities.

Permaculture seeks to reconnect humans with nature to bring forth abundance by regenerative means, guided by three principal ethics[4,6], often described as Earth care, People care and Fair shares. The first ethic is fundamental, since without a thriving planet, ultimately we have nothing, and so the soil, water and air must be viewed as sacrosanct to sustainability, and need to be protected and regenerated. The second ethic really embraces an integrated philosophy of living, in which humans (and the multitude of us) exert a profound impact on this planet, and if we flourish as part of a regenerative, rather than a degenerative design, the Earth will become abundant with us. So, people will have access to necessary resources, but we must use them without causing their deterioration. As labelled "Fair shares", the third ethic emphasises that each of us should take no more than what we need, but may be expressed alternatively as "Share the surplus", meaning that any surpluses are returned to the system overall to support the other two ethics. The useful recycling of waste back into the system is in accord with the third ethic, since there is no "waste" in nature, and the notion of the "circular economy"[7] is based on this. Together, the three ethics form a single closed paradigm, which places primary importance on the earth, with humans cast in the role of stewards, so that the impact of our actions upon the earth (and upon one another) help the environment to flourish, neither impoverishing it nor ourselves, in a mutually beneficial, and supportive system. Our future designs must work in harmony with, and not against nature, and rather than being the "dominant species" humans must become universal facilitators ("Earth stewards"), protecting and encouraging biodiversity across the world.

Green building

A truly "green" building would be made from wood, straw and similar materials that can be grown using natural, regenerative methods, and which may involve permaculture principles. However, what is described as "green building" often exploits renewable resources, such as sunlight (as harvested by passive solar, active solar, and photovoltaic methods), and plants and trees (*via* green roofs, rain gardens, and by reducing rainwater run-off). When high-performance buildings are considered, the embodied energy (emergy) can be as much as 30% of the total lifecycle energy consumption, and those with more wood than brick, concrete, or steel have the lowest emergy.

Within the concept of green design, the amount of waste generated by the occupants can be reduced using on-site solutions such as compost bins, which limits the volume of waste ending up in landfill sites. Similarly, much of what is produced when a building is demolished at the end of its life goes to landfill, but much of this can be recovered and turned back into building material. Clearly, the longer a building can be made to last (*i.e*. minimising inbuilt obsolescence) the smaller is the overall waste output, while materials such as wood are more readily reused. Wastewater from baths or washing machines (so called "greywater") can be used for irrigation, or to flush toilets and wash cars; rainwater can be collected from roofs to be used similarly.

To reduce the pressure on centralised wastewater treatment plants, human waste can be collected at source and converted into liquid fertiliser in a semi-centralised anaerobic digestion facility. This reduces the costs and energy use normally incurred in treating sewage, and produces nutrients for the soil, while creating carbon sinks and counteracting emissions of greenhouse gases. Such an approach also offsets the amount of artificial fertiliser needed for food production, and the associated high energy costs to produce nitrogen fertilisers in particular.

Although the issue of cost is often raised as an impediment to the construction of environmentally friendly buildings, since photovoltaics (PV), new appliances, and other technological innovations tend to be expensive, when taken over the entire lifecycle of the building, the returns are favourable, as has been summarised[8]: "Over 20 years, the financial payback typically exceeds the additional cost of greening by a factor of 4–6 times. And broader benefits, such as reductions in greenhouse gases (GHGs) and other pollutants, have large positive impacts on surrounding communities and on the planet." Thus the problem is that of a psychological hurdle, namely the up-front cost, rather than the lifecycle cost. This problem can be partly overcome with "building integrated photovoltaics (BIPV)" [9], in which PV materials are used in the roof, skylights, or facades of buildings (Figure 1), in place of those more typically used. In terms of cost, integrated photovoltaics are a more attractive approach than retrofitting existing buildings with solar panels, because their initial cost is offset by the reduced cost of materials and labour to put in place the elements that the BIPV replaces.

Britain's first energy positive house was opened recently in Wales, built in just 15 weeks at a cost of £125,000. The dwelling is very thoroughly insulated, and has batteries to store the electricity generated from the BIPV panels which serve as its roof. It is claimed that the Solcer House, in Bridgend, requires no external input of energy for 70% of the year, and according to preliminary calculations, its exports of electricity (to the national grid) generated during the summer are 1.75 kWh, for every 1 kWh it imports during the winter[10]. However, the UK government has now decided to scrap the zero carbon homes initiative and to reduce the feed-in tariff by 83%, both of which are likely to disincentivise the development of green buildings of this kind. However, green buildings which employ materials such as BIPV, can probably never be regenerative, and are sustainable only for so long as such technology can be manufactured and renewed: a period that might be extended by recycling fundamental elements and components, if sufficient energy remains available to do so.

Green business

The term "green business" encompasses all efforts by companies to produce energy and fabricate buildings in more efficient ways, with minimal detrimental environmental impacts, while maintaining commercial viability. More progressive organisations have centred their core activities around sustainability, with waste and pollution production as a key component. In addition to inaugurating tree planting and natural landscaping, some companies have introduced methods based on permaculture principles to meet their energy demands and building designs. Cynics have regarded such efforts as examples of "greenwash", driven by the desire of large companies to ingratiate themselves with environmental groups, but given the extent to which businesses, from the small to the very large (*e.g.* Apple Inc.), have adopted "sustainability" as a key element of how they function, it is likely that this tendency is real, and not just a ruse to secure more profits. Indeed, some businesses that have been flexible in their mode of operation, and embraced green approaches, have been very successful compared with more traditionally focussed companies. The Reading Climate Change Partnership (RCCP)[11] is based in Reading, the largest town in the UK. The overall intention of the RCCP is to reduce the town's impact on climate change, and its side-arm group, The Reading Climate Action Network (RCAN) http://www.readingclimateaction.org.uk/, aims to: "build a thriving network of businesses and organisations who will be at the forefront of developing solutions for reducing carbon emissions and preparing for climate change". A focus on businesses is due to the fact that commercial activity is responsible for 46% of Reading's carbon emissions, and it is aimed to reduce carbon emissions in Reading by 7%/year up to 2020. Many organisations have signed-up to RCAN and its emissions reduction target, but it is a moot point how truly sustainable the actions involved in meeting it are likely to be, and fewer of them are likely to be regenerative. However, it has been argued that while conventional business/capitalism can be blamed for many of the problems ("the world's woes", next section) that humankind now must confront, it is only the forces of capitalism that are sufficiently powerful to bring about the necessary changes toward sustainability and regeneration. A "helix of sustainability" has been devised, which represents an

Figure 1 *Solar panels, integrated in a block of flats in the Latokartano ecological housing area (Helsinki, Finland). https://upload.wikimedia.org/wikipedia/commons/6/66/Solar_panels_integrated_in_a_block_of_flats_in_Viikki_Helsinki_Finland.jpg Credit: Pöllö.*

ideal form of manufacturing in which the initial carbon feedstocks from plants, having passed through the stages of manufacturing goods, then maintaining them for as long as possible, are then recycled by composting to provide nutrients to grow the next generation of plants/carbon feedstocks (Figure 2). While this is clearly a "sustainable" strategy, further elements need to be introduced for it to become "regenerative".

The world's woes

Much attention is given to global carbon emissions and climate change, and rightfully so, yet this is just one feature of the "changing climate". Many challenges that confront humankind ("the world's woes") are often regarded as though they are individual problems, but actually are merely symptoms of a single problem – a too rapid consumption of resources of all kinds, and the attendant consequences. Some of these are:

- Carbon emissions: leading to global warming and climate change[12].
- Population increase[3]: 9.5 billion by 2050, possibly rising to 11 billion by 2100?
- Declining ("peak") resources[13]: water, oil, gas, coal, uranium, metals, phosphorus, soil, fish stocks.
- Land degradation[3]: soil erosion – desertification. 30% of global arable land has become unproductive in the past 40 years, and much of this has been abandoned. The connection[3] between soil and water *via* the hydrologic cycle means that the degradation of soil leads to increased drought, but also flooding.
- Loss of biodiversity: it is believed that we are in the midst of the "Sixth Mass Extinction", since the current rate of biodiversity loss is estimated to be at least as high as (or even higher than) occurred in the previous five mass extinctions[14].
- Increasing poverty: rising food costs, high prices of imported fertilisers[15], unfair global trade practices.

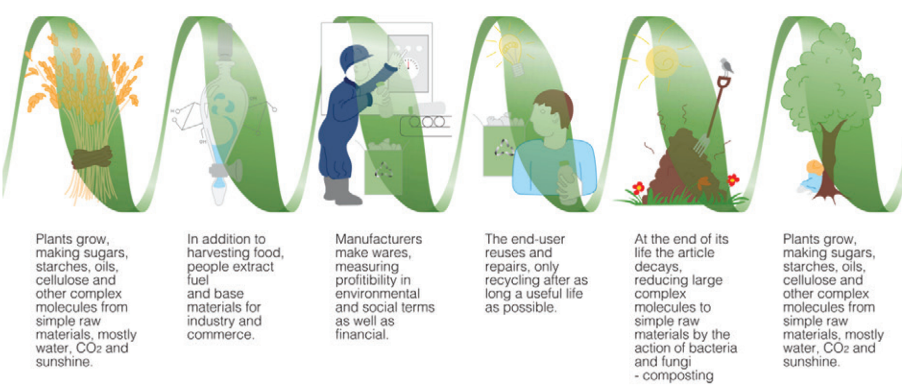

Figure 2 *The helix of sustainability – minimum environmental impact manufacturing and product use. https://upload.wikimedia.org/wikipedia/en/1/13/Helix_of_sustainability.png Credit: Design: Lynn Tucker, Graphic art: Astrid Erasmuson – The New Zealand Institute for Crop and Food Research.*

Building soil

The 68th UN General Assembly has declared 2015 to be the International Year of Soils[16], some objectives of which may be summarised:

- to create full awareness of civil society and decision makers about the fundamental roles of soils for human's life;
- to achieve full recognition of the prominent contributions of soils to food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development;
- to promote effective policies and actions for the sustainable management and protection of soil resources;
- to sensitise decision-makers about the need for robust investment in sustainable soil management activities aiming at healthy soils for different land users and population groups;
- to advocate rapid enhancement of capacities and systems for soil information collection and monitoring at all levels (global, regional and national).

This is part of a global effort to raise awareness of soil degradation, which is one of the critical "woes" of current civilisation. In France, the intention has recently been announced to increase the soil organic carbon by 0.4% per year[17] as a strategy to store carbon from the atmosphere in the soil, and to simultaneously improve soil quality and fertility. Soil and water are vital elements for life, and are connected by the hydrologic (water) cycle (Figure 3); soil is also a critical component of the carbon cycle, and hence preserving and rebuilding soil (improving its organic matter content, and structure) is fundamental to stabilising the climate and securing food and water supplies. Of all the actions we might take, building soil is truly sustainable and regenerative, and central to "Earth stewardship", which is one of the "possible future scenarios" discussed later.

Some salient facts about soil[18]

- One quarter of all the Earth's biodiversity is in the soil[19,20], *i.e.* that one-quarter of the number of all the organisms on the planet live in the soil, most of which are bacteria.
- 52% of the land used for agriculture is moderately to severely affected by soil degradation: mostly by erosion.
- It takes 200–1,000 years to form just an inch of soil, depending on the climate and other local conditions.
- Soil from agricultural land is being eroded at 10–40 times the natural rate.
- In the last 40 years, one third of the world's crop land has become unproductive as a result of soil degradation.
- It is estimated that 44% of the world's food production systems and 50% of world livestock are vulnerable, as a result of land degradation. This is likely to be exacerbated by climate change.

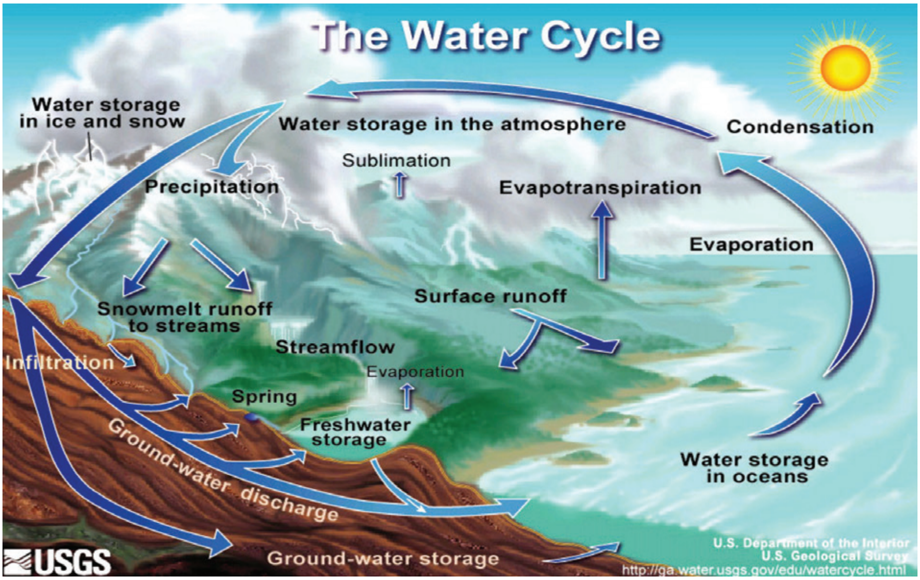

Figure 3 *The hydrologic (water) cycle. https://upload.wikimedia.org/wikipedia/commons/9/94/Water_cycle.png Credit: Courtesy of the US Geological Survey.*

- Food production in 2050 will need to be 70% greater than it is now, to feed an expected population that has risen to 9.5 billion (from 7.3 billion), and with relatively more meat being consumed.

Ways to protect and regenerate soil[18]

- Avoid bare ground: reforestation, planting cover crops (peas, beans, buckwheat, clover, *etc*.).
- Build soil organic matter (SOM); no-till farming methods.
- Shield the soil through the use of sand fences, shelter belts, woodlots and windbreaks; plant trees.
- Farmer-managed natural regeneration: five million hectares of barren land have been "reforested" in Niger, at a density of 40 trees/hectare.
- Protect existing forests: huge stores of carbon both in the biomass and the soil, and oxygen producing bodies, "the lungs of the Earth".
- Mulch from pruned trees, and straw to cover fields: increasing soil water retention and reducing evaporation.
- Tree planting: aids in the infiltration of water into soil, and reduces flooding.
- Build the "soil food web": one teaspoonful of healthy soil can contain over one billion microbes. The active presence of the soil fauna and flora improves the cycling of nutrients and water in the soil.

Zero Carbon Britain

The Centre for Alternative Technology has devised an overall strategy Zero Carbon Britain (ZCB)[12] for providing energy in the UK with zero carbon emissions by 2030, which involves cutting our overall use of energy from that in 2010 by 60%.

ZCB can be considered as a "Green-tech stability" approach, as is discussed in the next section. A large scale conversion of end-use energy to electricity is envisaged (eliminating oil, gas and coal) which is produced from renewable resources, particularly wind power and biomass. Energy use in buildings accounted for 45% of the UK's total energy budget in 2010, and in ZCB it is assumed this can be reduced by 50%, by retrofitting existing buildings, implementing "passivhaus" standards for new build, and improving internal temperature control.

By reducing the total distances travelled per person – with more walking, cycling, use of public transport, and switching to electric vehicles – the energy demand from transportation could be cut by 78%. In this scenario, car travel is reduced from 82% to 56%, and the number of air miles is cut by 60%: 90% of road transport uses electric vehicles (cars, vans, coaches and buses), while carbon neutral synthetic liquid fuels and hydrogen power the remaining road passenger vehicles, and the rail network is 95% electrified. Hourly modelling of the renewables mix in ZCB indicates that we could produce excess energy for 82% of the time, while at other times, the use of carbon neutral synthetic gas (for energy storage over weeks or months), and by shifting energy demand with "smart" appliances, batteries, pumped storage, heat storage, and hydrogen (for shorter term storage: hours or days).

Significant changes to land use and diets are also central to ZCB, with a reduction in agricultural CO_2 emissions by 75%. 75% of the land area currently used for grazing animals could be repurposed, with a doubling in the forest area to 24% of the total UK land area. While the implementation of alternative technologies is critical to achieving ZCB, it cannot be achieved without lifestyle changes too, *e.g.* although most people would still travel in cars, the individual ownership of them would be reduced; more drastically, the required cut in air miles to 60% would reduce air travel to the level of the 1970s.

The large amount of biomass required would change the appearance of the countryside and require a reduction in grazing livestock, with according dietary amendments. The net result would be a shift in the livestock/plant protein ratio from 55 : 45 to 33 : 67 (with less meat and dairy being consumed, but more beans, nuts, cereals and vegetables) with significant reductions in both land area use and carbon emissions. It would also mean a healthier and more secure diet (with 85% of our food being grown in the UK) and more people working in land-based jobs.

Possible future scenarios?

The demands of civilisation have accelerated from those of pre-industrial sustainable culture, in terms of our use of energy and other resources, population and pollution. Access to the fossil fuels has been the main driver of change, through a period of massive industrialisation ("modernism"), which has brought us to the present fulcrum of uncertainty over our future direction: David Holmgren (one of the founders of permaculture) has identified four possible scenarios[21]. The first is "Techo-fantasy", where some new form of energy is discovered which not only allows the present level of consumption to be maintained, but the according social, environmental and cultural debt can be dealt with, and on *ad infinitum*.

The second is "Green-tech stability", where we descend from the current unstable situation of overuse of resources, environmental destruction *etc.* with more use of renewable energy and eco-friendly technology, but the status quo of industrial affluent society, and its economy, largely remains intact. This is popular with many environmental groups and with progressive political parties.

Scenario three is "Earth stewardship", which involves coming to terms with our dependence on renewable resources such as soil, plants, animals and forests, as was the case for those living in the pre-industrial era. This implies a period of continual change, lasting probably centuries, where societies adapt to using inexorably less energy and resources, as is available to each succeeding generation. Naturally, this is quite contrary to notions of steady-state, and stability.

The fourth scenario is "Atlantis", which is the precipitous and catastrophic collapse of most of the structural elements of civilisation, with a consequent calamitous plummeting in global population.

Within this framework, Holmgren places permaculture as a design path toward Earth stewardship. There is a resemblance between the early phases of both the Green-tech stability and Earth stewardship scenarios, but then they diverge massively, so that over centuries, a more likely symbol for the solar economy is a tree, rather than a photo-voltaic panel. We cannot make choices between the four scenarios, and indeed all of them exist in the world today: as time progresses, they will be manifest in greater or smaller degrees, and in alternative forms in different regions of the world. Critical drivers will be resources, especially of energy, but ultimately it seems likely that Earth stewardship is the only sustainable scenario, and indeed the only one that is regenerative of essential resources.

References

1. https://ipcuk.events/conference
2. https://ipcuk.events/convergence
3. Rhodes, C.J. (2014) *Sci. Prog*., **97**, 97.
4. Rhodes, C.J. (2012) *Sci. Prog*., **95**, 345.
5. https://en.wikipedia.org/wiki/Horror_vacui_%28physics%29
6. http://deepgreenpermaculture.com/permaculture/permaculture-design-principles/2-each-element-performs-many-functions/
7. http://www.ellenmacarthurfoundation.org/circular-economy
8. http://thinkprogress.org/climate/2010/09/24/205805/costs-and-benefits-of-green-buildings/#
9. Rhodes, C.J. (2010) *Sci. Prog*., **93**, 37.
10. http://www.nce.co.uk/news/structures/uks-first-energy-positive-house-launches-as-government-scraps-zero-carbon-homes-initiative/8686527.article
11. http://www.reading2020.org.uk/climate-change/
12. http://zerocarbonbritain.org/zcb-latest-report
13. Sverdrup, H.U., Koca, D. and Ragnarsdottir, K.V. (2013) *J. Envir. Sci. Eng*., **B2**, 189.
14. Ceballos, G. *et al.* (2015) *Sci. Adv.*, **1**, e1400253 DOI: 10.1126/sciadv.1400253
15. Cordell, D. *et al*. (2009) *Global Environ. Change*, **19**, 292.
16. http://www.fao.org/soils-2015/about/en/
17. http://www.theecologist.org/blogs_and_comments/commentators/2985914/frances_plan_to_increase_its_soil_carbon_is_an_example_to_the_world.html
18. http://www.resilience.org/stories/2014-05-30/for-our-children-s-earth-rebuilding-the-soil-sustaining-the-future
19. http://ec.europa.eu/environment/archives/soil/pdf/soil_biodiversity_brochure_en.pdf
20. http://www.fao.org/3/a-i4551e.pdf
21. http://www.futurescenarios.org/