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What Has Nature Ever Done for Us?

How money really does grow on trees

Tony Juniper

Foreword by
HRH The Prince of Wales

PROFILE BOOKS

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The East Anglian Fens were once a mosaic of wetlands, swamp forests and grasslands that stretched from north of Cambridge to where the coast of eastern England meets the North Sea at a huge shallow bay called The Wash. Today just four tiny fragments of this once extensive natural habitat remain, surrounded by some of the most intensively farmed agricultural land in Europe.

The taming of the Fens was one of the great milestones in the history of farming in England. For centuries farmers had battled nature and water for control of the land, but in the seventeenth century a wholesale transformation from wild wetland to productive modern farmland got underway, masterminded by Dutch engineer Cornelius Vermuyden. He straightened rivers and drained vast areas with wind-powered pumps using techniques developed in Holland.

A major event in Fenland conversion came later, however: the drainage of Whittlesey Mere. Until the early 1850s this reed-fringed expanse of water was the largest lake in lowland

England. In summer it covered some 7.5 square kilometres. In winter it almost doubled in size and in places was more than 6 metres deep. It was full of fish and a magnet for birds.

While the Dutch-inspired construction of new channels and wind-powered drainage had made a huge impact on the Fens, it was the installation of the recently invented steam-powered centrifugal pump that brought about the rapid demise of this particular natural landscape. The new pump could shift 70 tonnes of water a minute, and as a result of one being put in next to Whittlesey Mere the traditional summer sailing and fishing, and winter wildfowling and skating, came to an abrupt end. Other changes were also soon apparent.

Holme Fen lies to the south of the city of Peterborough and is one of those four places where anything resembling natural habitat remains today. In 1851 it was at the edge of Whittlesey Mere. In 1852, anticipating some dramatic implications from the ongoing drainage works nearby that was converting open water and reed-beds to wheat fields, local landowner William Wells put in place a unique and, as it turned out, very effective environmental monitoring project.

Wells asked his engineer friend John Lawrence to sink a tall iron post into the ground. He procured one that was said to have come from the iron-framed Crystal Palace that hosted the Great Exhibition in London the previous year. The post was buried into the peat and fixed at its base to timber piles that were driven into the underlying clay to make sure the post didn't move. The top of the post was at ground level.

While the post has remained the same size and stayed where it was, the land has not. Today the top of the iron column towers some 4 metres above the surface of the now desiccated fen. As the ground has contracted, some of the surrounding agricultural land now lies more than 2 metres below mean sea level, making it the lowest point in the British Isles. The neat rows of fields with long straight roads and drainage ditches today give few clues that this part of north Cambridgeshire was once the bed of a substantial lake.

The activities that led to the land literally shrinking were motivated by the financial rewards to be earned through farming the rich peaty soils. These valuable sediments had accumulated since the end of the last ice age, when sea levels had risen, blocking the exit of Fen rivers to the sea. This caused the land to become water-logged; dead vegetation didn't completely rot and this and other organic material accumulated as deposits that today are peat. The peat took some 8,000 years to build up and was to become some of the finest farmland in the UK. And, like all farmland, its productivity and value is first and foremost determined by the character of its soil.

Out of sight and out of mind

Beneath our feet, out of sight and often out of mind, soil is probably the least appreciated source of human welfare and security. More than simply a prerequisite for farming and food production, it is a profoundly complex web of interactions that enables many of the Earth's life support systems to function.

Soil is the medium through which the world of life (biosphere) meets the world of rocks (lithosphere). This is not simply reflected in the fact of plants growing out of the ground. It is a highly complex subsystem of our living planet where a commingling of these two worlds takes place. As was found in *Biosphere 2*, it is also where dynamic relationships between the atmosphere and life are sustained. It is of vital importance and yet it is no more than a thin fragile skin. This is even more the case when seen against the scale of the atmosphere above and the geology below.

Soil actually seems far too small a word to describe such a complex and multifunctioning system, especially when one considers the ways in which the different components of soil can vary. For the make-up of soil is hugely diverse. Its essential components are weathered rock, once-living things that are now dead, living things that are still alive, gases and water. A very approximate breakdown of the proportions of these would be rock at about 45 per cent, air 25 per cent, water 25 per cent and organic material 5 per cent. Of course, these proportions vary hugely, with for example peaty soils comprising mainly organic matter.

Often the most important factor in the character of soil is geology. Sandy soils are gritty and formed from rocks such as limestone, quartz or granite, or from glacial, wind-blown or riverine deposits. Silty soil has finer particles and is often very fertile, although prone to erosion by water. Another major influence on the character and properties of soil is the type and amount of biological material it contains – this can be comprised of pretty much anything that has been alive, including the decaying remains of soil fauna, leaves, wood and roots.

Soil organic matter performs a range of important functions and is vital in determining how soil functions. For example, organic material in the soil can hold up to twenty times its own weight in water, and thus renders soil more resistant to the effects of drought. By storing water, soils can also reduce the risk of flooding during high rainfall periods.

The organic material in soil contains the carbon-based molecules that are the energy source that fuels what is the most important component of all – the living part. And when it comes to the complement of animals, plants and microbes living and interacting below ground, the statistics quickly get quite dizzying. For example, it is estimated that ten grammes (that's about a tablespoonful) of healthy soil from an arable landscape is home to more bacteria than there are people on Earth. And these bacteria might be comprised of representatives from some 20,000 species. It is not only the numbers and diversity that is impressive – on a hectare of arable soil (that is, a patch measuring 100 metres by 100 metres) there can be a volume of bacteria equivalent to the volume of 300 sheep!

In addition to the truly tiny organisms – that is, the bacteria, protozoa and nematodes – are larger creatures, including earthworms, centipedes and various insects. This vast mass of complex living organisms undertake a number of vital jobs.

One function is decomposition. As the term suggests, this is literally the business of breaking things down to their constituent parts – and in the process liberating nutrients, thus enabling new growth. Those numberless trillions of worms, bacteria and protozoa are thus at the very base of the ecological processes that enable the productivity of living systems – at least most of those on land.

Decomposition is also so important because it is the energy source that powers the processes going on in the soil. By breaking down the carbon-based molecules in the plant and animal remains in the organic matter, the bacteria, fungi, nematodes and protozoa fuel their own growth and reproduction. Most soils are complex systems that we are only just beginning to understand. And, while for example the pivotal importance of earthworms has been known for some time, it is comparatively recently that science has permitted a better understanding of the subtle roles played by other soil organisms, including fungi.

The benefits of dirt

Irrespective of their complexity, soils obviously deliver some fundamental benefits for humankind. Over 90 per cent of our food depends on functioning soil for its continued production (the exceptions include wild sea fish and the tiny amount of produce grown hydroponically in greenhouses).

No matter how much processing, packaging and marketing goes into modern food, the production of most of it depends in the end on a vast army of nematodes, microbes and worms, many of which have not even been granted a scientific name. The next time you pick up a packet of peas or crisps, remember who the ultimate producers of those products were – and it's not only the famous brands on the packet!

It thus seems all the more remarkable that for many people soil has taken on the cultural label of 'dirt', and as such is something to be avoided, washed off or concreted over. The inconvenience of 'dirt' has been the motivation for many gardens to be sealed beneath wood, tarmac or gravel and treated to liberal doses of herbicide.

And it is not only for the future food that we should pause for thought and look again at our cultural relationship with soil. Another aspect that has been on the political agenda in recent years is the role of soils in carbon cycling and storage. Organic matter, including the living components of soil such as roots and microbes, are important in this respect.

While many people have changed their lightbulbs, left their car at home and debated with their friends and family the pros and cons of wind turbines, how many have thought about soil as one of the main ways we might respond to rising levels of atmospheric carbon dioxide?

Yet researchers have estimated that in the UK alone in the order of 10 billion tonnes of carbon is stored in soils: that's more than in all of the trees in the forests of Europe. The peat-rich soils of the English uplands alone contain organic material with more carbon than all the trees in the UK and France added together. In the lowlands too, there is significant carbon held in the soil.

To put this factor of planetary stability into a wider context, it is estimated that the amount of carbon in the world's soils is more than that found in the atmosphere *and* all plants combined. The iron post rising from the desiccated surface of Holme Fen testifies to how that fact is subject to ongoing change.Another issue that has followed carbon on to the international agenda is the provision and efficient use of fresh water. Soils help purify water by enabling the precious liquid to enter rocky aquifers beneath them, rather than running off the land. Soils also store a lot of water themselves. These properties help supply most of the world's population with fresh water.

According to one estimate from the Environment Agency for England and Wales, a single hectare of soil has the potential to store and filter enough water for 1,000 people. Promoting the ability of soils to hold water will also help sustain food production, especially in times of low rainfall. With climate change causing more extreme weather, including droughts, the capacity of soils to store water will be an increasingly important factor for crop productivity in terms of yield and quality, and indeed food security as a whole.

Soil stress

Farming can, however, put significant stress on soil systems. Ploughing not only exposes soil to the air, but it breaks down soil structure, making the disaggregated soil particles highly vulnerable to erosion. In dry spells, when soil can lose its cohesion, the wind can whip soil from the land to form plumes of dust that can sometimes travel for thousands of miles. Other forms of soil degradation can lead to the same outcome. On 6 March 2004, a NASA satellite captured a remarkable image of a massive dust cloud heading out across the Atlantic Ocean from North Africa. It extended across about a fifth of the Earth's circumference. The air currents took a huge quantity of soil out over the sea as far as the Caribbean.

Soil turning to dust and being taken by the wind is not only a challenge for the developing world. In the 1930s, United States farmers in the Midwest were confronted by the effects of soil degradation after intensive farming destroyed the protective cover of vegetation and hot dry weather turned the soil to dust. High winds in 1934 transformed an area of some 50 million acres of once productive agriculture in parts of Oklahoma and Kansas into what became famously known as the Dust Bowl.

Soil erosion is often caused by the wind, but in some regions the effects of rainfall can be more pronounced, as seen by the eroded soil in rivers turning the water the colour of cocoa or tea. This is where China's vast Yellow River gets its name, as ochre-coloured soil is eroded and washed toward the sea by the river's mighty transporting power. The middle and upper reaches of its catchment suffer the most serious soil erosion in the world. The degraded area here is more than one and half times the size of Britain and loses up to 1.6 billion tonnes of soil each year.

The loss of topsoil is the most serious symptom of soil degradation and is regarded as a major problem in many regions, including parts of the USA and Australia. Recent estimates suggest that each year more than 10 million hectares (25 million acres) of crop land is degraded or lost, as wind and rain erode topsoil. According to one authoritative estimate, an area of agricultural land about ten times the size of Britain has been degraded to the point where it is effectively of no use for food production. Globally, and since the mid-twentieth century, about a third of all farm soils have become degraded to some degree.

Soils generally take a long time to accumulate: a reasonable working figure is about 1 millimetre per year. Rates of soil erosion in many areas are far higher than this, and the loss of topsoil can be seen as effectively the depletion of a nonrenewable resource. In parts of the United States soil is being lost ten times faster than it is being replenished; in parts of China and India it is estimated that soil losses exceed soil formation rates by a factor of forty.

Despite these dramatic demonstrations of soil loss, in many places the effects of erosion can appear minimal, too slow year by year for the human eye to notice. But over longer periods, the loss of, or damage to, soil can lead to major change, as the metal post at Holme Fen testifies. In that case, drainage first caused the peat to shrink, and then as it was exposed to the air it became oxidised and 'evaporated' when oxygen molecules united with carbon in the organic matter to form carbon dioxide. It literally turned into thin air!

And that process continues as peat soils are drained and ploughed. In the Fens of eastern England peat loss and shrinkage continues at a rate of about 1 to 2 centimetres per year. The implications for food production in this important agricultural region are clear. In some places the peat has already eroded to the point where the underlying clay is exposed. And this is not only an issue for food. Recent research estimates that the exposed lowland peatlands of England could be emitting nearly 6 million tonnes of carbon dioxide per year.

Not only can soils contribute to climate change, they are also vulnerable to its impacts. While warmer temperatures and elevated carbon dioxide concentrations in the air might increase the rate of plant growth, and therefore increase yields in some places, more extreme conditions might be expected to cause an overall negative effect. This will include, for example, increased rates of erosion due to more intense rains and reduced soil moisture due to drought and changes to seasonal rainfall.

Soil is under pressure, and its ability to provide a full range of essential goods and services has been reduced, in some places quite dramatically.

How much soil can we lose?

One person who spends a lot of time thinking about soil is Professor Jane Rickson. She is the leader of the Soil Conservation and Management group within the UK's National Soil Resources Institute and a leading soil scientist. Her research lab at Cranfield University in Bedfordshire, England, has an array of facilities to enable forensic investigations into how soils work.

One experimental apparatus includes a trench full of soil with full-scale machinery running over it to simulate the causes and effects of soil compaction. Another permits the study of how different stocking densities of farm animals affect soil and how farmers might manage land to reduce erosion. There are rainfall simulators that enable any kind of precipitation to be created, from light mist to an intense tropical storm, to see what effects this can have on different soils. There is a machine to see how raindrops wobble and spin as they fall and how this affects soils when they hit the ground. These and other research tools help build more detailed knowledge of what is happening to soils, and why.

But while Professor Rickson's research work is based on a very detailed understanding of how soils work, it is her conclusions about whole soil systems that are most striking. 'The soil system is more than the sum of its parts,' she says. 'We have excellent soil chemists, soil biologists and soil physicists who are experts on different aspects, but it is the whole system that is most vital to understand. It seems to me like a living engine. It is self-regulating and ticking over. Take one component out and the engine stops working.

'Soils are being damaged and depleted quicker than they are being replaced. Rates of loss have to be balanced with rates of formation for soils to be sustainable. The net loss of soil means that different services cannot be sustained, including food production. But how much soil can we lose before we begin to