Sustainability out of the past: how archaeology can save the planet

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Abstract

There has been much interest in the failures of the past and the environmental disasters that ensued because of poor land management practices. I argue that the successes of the past are of equal importance, and this is increasingly recognized as early agricultural techniques are rediscovered and reinstated. Some of these systems are not only more sustainable than modern technologies, but more resilient in the face of environmental extremes. Ancient engineering and agricultural methods are often more appropriate for developing countries than modern technologies based on fossil fuel and imported materials. As global warming and desertification increase, it is crucial that we learn how to deal with marginal environments in ways that are sustainable and accessible to people in developing countries. Sustainable agriculture can also benefit the developed world by increasing yields, promoting biodiversity and supporting the rural economy.

Keywords

Sustainability; water harvesting; *chinampas*; Negev; raised fields.

Introduction

Considerable changes have taken place in the countryside of the developed world in the last 200 years, changes that have accelerated throughout the twentieth century. Biodiversity has plummeted as fields have been planted with single crops and sprayed with pesticides and weed killers to produce monocrops. Hedges and fence lines have been removed to create larger fields for crops which can be mechanically planted, fertilized and harvested. Machines have taken over most of the manual labour on farms in the developed world, changing the nature of rural life and vastly diminishing the number of jobs in the countryside. Animals are farmed more intensively, with higher stocking densities and greater distances to abattoirs and markets.

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Agriculture is a vitally important aspect of our past, present and future, but farmers do a lot more for us than just growing food: they also manage the countryside. Many nations regard the countryside as an amenity for everyone to enjoy, and many endeavour to preserve the landscape and the remaining native plants and animals that have withstood the deprivations of industrialized farming. Equally, there is now increasing interest in traditional land management and a return to more harmonious and sustainable ways of growing food and managing the countryside.

The methods used in traditional (i.e. pre-industrial) agriculture developed over thousands of years, through the process of trial and error. There are many instances where great ecological and environmental damage was done (cf. Diamond 2005), but also instances where soils have been improved and fertility increased. Many experiments have demonstrated that traditional, sustainable agriculture can actually produce *higher* crop yields than industrialized farming (Erickson 1988; Pearce 2001, 2002; Pretty 1998a: 84–90). The study and regeneration of appropriate technologies from the past can therefore transform the countryside, revitalize rural economies and help people in developing countries to maintain their independence (Scialabba and Hattam 2002). Engineers call these solutions 'intermediate technology', and the key is that they are sustainable, have little or no reliance on fossil fuels and use local materials. Obviously there are other obstacles – political instability, war, issues of land ownership and other economic considerations – but these are not the focus of this paper, which aims simply to demonstrate that we already have the technology to make substantial improvements in the way we manage the countryside.

In this paper I will review some regions where ancient technologies are being reinstated, beginning with wetland areas. Since wetlands will increase exponentially with global warming, this is a key consideration.

Wetlands

Wetlands are regarded as an obstacle to agriculture, at least since mechanization has obviated the need for the low-lying hay meadows which fuelled the traction animals that once pulled the ploughs. Drainage has been a key undertaking in agriculture, from small-scale drainage of boggy ground to the reclamation of vast areas like the Dutch polders and the Cambridgeshire fens. Today, living in a wet landscape is regarded as less than ideal.

There are, however, many ways of living in the wetlands. In the 1960s, huge areas of mounds, ridges, canals and causeways were discovered in Bolivia, and aerial surveys have since shown that these cover many tens of thousands of hectares across the countries of South America (Denevan 2001: 216). There are over 82,000 ha of raised fields around Lake Titicaca in Peru and Bolivia, which were re-created by a team of archaeologists in a five-year experiment using traditional, pre-industrial farming methods (Erickson 1988). The land was cropped continuously, with only the lake material as fertilizer – an ideal source, given that nitrogen-fixing algae were part of the wetland ecosystem. The team's crop of potatoes yielded ten metric tonnes per hectare, compared to the local farmer's one to four tonnes per hectare, thus far exceeding the yield of any modern farms in the region (ibid.). The practice among the farmers of the Lake Titicaca basin – where the soils are classed as marginal – had been to plough the ancient ridges flat and cultivate for three to four years, before leaving the fields to lie fallow for three to ten years. Erickson's research showed that raised fields could be farmed continuously, simply using the supply of nutrients from the canals. The re-instatement has been successful in areas with the economic and political institutions to support it, and raised field agriculture is now spreading throughout the region.

In the Valley of Mexico there is another pre-Columbian wetland system still in operation, although much diminished and degraded. The raised fields in Mexico City, originally the site of the Aztec capitol Tenochtitlan, are called *chinampas*, and they are so productive that these artificial islands sometimes produce more per hectare than the local agricultural research station (Werner 1992). The soil has a fine texture that allows water to be drawn up from the water table by capillary action, so it neither becomes waterlogged nor dries out (ibid.). It has been estimated that the remaining *chinampas* could supply Mexico City with a quarter of the vegetables it requires (ibid.). Yet, instead of promoting the *chinampas*, the government provides grants to buy tractors (which would compact the soil) and chemical fertilizers (which would be deleterious to the water quality).

Desert agriculture

Global warming is also causing desertification and the expansion of arid regions, but the deserts can be extremely productive if the land is sympathetically managed. In 1870 an English explorer described a number of ruinous settlements, stone walls, cisterns and check dams, 'all of which bespeak a former state of fertility and industry' (Palmer 1871: 356). Woolley and Lawrence (of Arabia) also discussed these features in 1915, astutely suggesting that the Byzantine agricultural systems of the Negev must have depended entirely on stored water (Woolley and Lawrence 2003 [1914–15]: 42).

The archaeological remains of the Negev desert were comprehensively mapped in 1948 (Evenari et al. 1971). The team identified stone mounds, walls and terraces along the hillsides covering hundreds of thousands of hectares, as described by Palmer in 1871. All were linked with artificial canals leading to the wadis, the river canyons, and within the wadis there were farms dating from the Nabatean period (around 2000 years ago) to the Byzantine (ibid.).

These extensive remains were part of a water harvesting system which worked because of the fine silt soils of the Negev (Evenari et al. 1971: 136). When it rains the soil forms a crust and the water runs off until it hits stones, whereupon it sinks into the ground (ibid.). When the stones are raked up into piles, the water runs off the bare soil more easily. Evenari et al. argue that the point of the stone clearance is to encourage the water to run down the hillside into channels, which carry it to the fields and cisterns. Modern experiments have supported this hypothesis, demonstrating that stone removal increases water run-off by almost 250 per cent (Lavee et al. 1997). The actual rainfall in the desert is only 100mm a year, but the cultivated area of a run-off farm would have received the equivalent of 300–500mm of rain per year (Evenari et al. 1971: 109).

Each farm had a number of collection channels and an underground cistern, and all the water in the system was controlled by channels and sluices, thus controlling flash floods and assuring the force of water did not damage the terraces. During flash floods, the water cascades gently from terrace to terrace down the wadi. Some water sinks into the soil and some is pooled behind the terrace walls, so that it deposits its load of silt. Consequently, the terraces control erosion as well as harvesting rainwater (Evenari et al. 1971: 97). There were thousands of these farms in the Negev, with systems that developed over time.

Two of the farms were reconstructed and put back to work, immediately prior to the most extreme drought ever recorded in the Negev (Evenari et al. 1971: 191). While crops withered and died all across the region, on the experimental run-off farms they had a good harvest – despite using considerably less water than local irrigated farms (1971: 208). Modern irrigation tends to overwater crops (Goldsmith and Hildyard 1984) and causes salinization of the soil (Brady and Weil 1999: 384; Goldsmith and Hildyard 1984).

The run-off system functions without raising the water table, and therefore does not cause salinization. There was also an unexpected discovery on the experimental farms: giving plants and trees less water meant the fruit was unusually sweet (Evenari et al. 1971: 362), and the medicinal plants particularly potent (1971: 194).

There is little interest in re-introducing water-harvesting systems in Israel, partly because of the difficulty of using tractors on the terraced fields. Evenari's team tried using a tractor initially, but found it was unviable and resorted to using a rototiller. The Bedouin use camels to draw wooden ploughs, which are lighter and more appropriate for the local soils. The unpredictability of the rains is another matter; terraced fields hold variable amounts of water, and it has been argued that they are unsuitable for modern agriculture (Zaban 1981). However, this concern has not prevented the idea from spreading to other Middle Eastern countries as well as Afghanistan and North Africa.

Cisterns

The local Bedouin still grow crops on the surviving ancient terraces, and use the ancient cisterns that hold the water from the run-off systems (Evenari et al. 1971: 159). These underground cisterns are key to living in the desert. They range in size from individual household cisterns to huge, municipal constructions such as those found at Petra and Masada. Cisterns for water storage date back to the Chalcolithic, before 3000 BC (Wåhlin 1995), and household cisterns occur across the Middle East, India and the north of Africa. The earliest historical account of them is written on the Moabite Stone in around 850 BC.

A census in Jerusalem in 1921 recorded 7000 cisterns for collecting run-off water, but today they are almost all filled with sediment and rubbish (Wåhlin 1995); similar declines have been noted in Jordan (Fardous et al. 2004) and India (Agarwal and Narain 1992). Water supply in these regions has been centralized and piped in from large reservoirs. This means that in Jordan, for example, 92 per cent of the annual rainfall now simply evaporates (Wåhlin 1995). Recent research in Jordan is demonstrating the viability of reinstating rainwater-harvesting systems and other sustainable practices (Al-Bakri et al. 2008; Fardous et al. 2004; Oweis et al. 2004a), and it has been predicted that water harvesting could save 10–15 per cent of the water currently being lost, amounting to 6.6 billion cubic meters (Oweis et al. 2004a).

Qanats

Another traditional technology which is being reinstated is the system of qanats. Qanat systems are underground canals which bring water from the hills onto the agricultural plains. The channels extend the habitable land, while protecting the water from evaporation in the desert heat. Qanats (also known as *karez* or *kariz*, *falaj*, *aflaj*, *foggara* or *khettara*) are widespread across Asia and North Africa (Dutton 1989; Lightfoot 2000). The Assyrian King Sargon II referred to qanats in the eight century BC (Lightfoot 2000), but they originated before 1000 BC in Persia, now Iran (Hillel 1994: 192).

Qanats were widely used all across central Asia until the twentieth century; Iran still had 22,000 qanats in the 1950s, with more than 170,000 miles of underground channels that supplied 75 per cent of the country's water (Wulff 1968). Unfortunately, in most regions they are redundant, having been replaced by deep wells with power pumps that deplete the aquifers and lower the water table (Cressey 1958; Hillel 1994: 192; Karrou and Boutfirass 2004).

Qanat systems still operate in Iran, North Africa, China, Pakistan, the Arabian peninsula and Afghanistan, and there is a plan to re-develop the qanats (or '*aflaj*') in Oman (Dutton 1989). The countryside in Oman is becoming depopulated as rural workers move to the cities, and a vast proportion of the country's food is now imported. The qanats have fallen out of repair, and the government commissioned a study to look into reinstating them. This research suggests that with some simple adjustments Oman's rural economy could be completely revitalised (ibid.): first, the qanats have to empty into storage tanks, so less water is wasted; second, solar-powered pumps are needed to work the system of sluices. This would enable water delivery to all the farmers every day, rather than every six to eight days. Local farmers could then grow cash crops that depend on greater quantities and a more regular supply of water, and labour costs would also be reduced (ibid.).

It has been argued that qanats are unsafe, waste water and depend on child labour, and should therefore not be re-developed (Issar, interview with Pearce 2004). In fact, the system could operate perfectly well without child labour, while the addition of water cisterns would avoid wastage (Dutton 1989). There are plenty of solutions that would improve safety, for example by lining the channels with tiles (used in Iran: Cressey 1958), or concrete, or other materials. In the Xinjang district of China the *karez* are sealed so that the soft bedrock does not collapse, and underground reservoirs are being built to prevent leakage and evaporation (Kimoto et al. 1991).

The changing climate makes it imperative that these ancient systems are reinstated. Desertification affects more than 110 countries and threatens the survival of more than a billion people (UNCCD 2009), and the population of the arid regions is increasing even faster than the world average (Hillel 1994: 33). Drylands on every continent are being degraded by over-cultivation, overgrazing, deforestation and poor irrigation practices (UNCCD 2009). This is due to ignorance, war and drought, and a combination of economic and social pressures and inequalities.

Reinstating old systems does not mean sticking slavishly to the old techniques. By integrating modern technology and new ideas it is possible to create systems that are more effective than before. A new approach to irrigating the desert is drip irrigation, which delivers water in very small quantities, directly to the roots of the crops (Hillel 1994: 221). This system saves water, limits weed growth, reduces the likelihood of waterlogging and salinization and puts less stress on the crop (1994: 224). It is a modern form of another ancient practice, that of placing semi-permeable clay pots in the ground, filling them with water and covering them with tiles, so that the water slowly permeates into the soil (Bainbridge 2001). This practice, first mentioned by Fan Sheng-chih Shu in the first century BC, is even more efficient than modern, piped drip irrigation (Bainbridge 2001).

With good management, the desert can support quite a high population, as we can see in evidence from the Negev and from experiments in West Asia and North Africa (Oweis et al. 2004a). The problems arise when land is over-grazed, the water tables are depleted by deep wells, trees are over-exploited for firewood and the soil is not protected from erosion. There are a number of current research projects which demonstrate that many of these degradations can be reversed, revitalizing the landscape and the economy in arid zones (Agarwal 2001; *Afrol News* n.d.; Adeel et al. 2008; Oweis et al. 2004a; Reij et al. 2009).

Soil erosion

Rebuilding work in Yemen provides a good example of what can be done to reverse land degradation. In the Middle Ages the extensive agricultural terraces in Yemen were regarded as one of the wonders of the world, and a wide range of arable crops were grown in the region (Varisco 1991). In the 1960s and 1970s the Yemenis began to modernize their agricultural systems, concentrating on the valleys and coastal zone where mechanization was more viable. Political instability and other problems led to the abandonment of many of the terraced hillsides, and without maintenance many of the walls broke down and the soil eroded (ibid.).

This caused problems in the valleys, because terraces check the flow of water as well as preventing soil erosion. The increased flow of water eroded the valley stream beds in agricultural land (Al-Hebshi 2005), valleys were buried in large quantities of silt washed down from the hillsides and deep wells depleted the water table (Varisco 1991). Fortunately, this process is now being reversed in some regions, where terraces are being rebuilt. Greenhouses and drip irrigation are creating cash crops in a sustainable way, and the renovated terraces are saving the soil on the hillsides while halting sedimentation in the valleys (Aw-Hassan et al. 2002; Moustafa and Mukred 2002).

On a global scale, it has been estimated that 24 billion tons of soil are lost to erosion every year, and this has been succinctly described by Montgomery (2007) as ‘skinning the earth’. Agricultural terraces are part of long-established cultural ecosystems, which have been functioning effectively for hundreds of years in some places and for millennia in others. Dryland terrace systems were built in Africa, the American South-West, South America and the Middle East, and wet terraces are used in Japan, Korea, China, Southeast Asia, Ceylon, Madagascar, the Himalayas, Hawaii and India (Allen 2004; Denevan et al. 1987; Donkin 1979; Spencer and Hale 1961). Terracing conserves soil and water, in sharp contrast to the on-going modern forestry practice of clear-cutting timber on steep hillslopes, which allows the soil to erode straight into the valleys, choking lakes and streams with sediment, destroying water quality and increasing flood risk.

Intercropping

Intercropping, or planting several species together, is another form of intensive, sustainable agriculture which was traditionally practised all over the world, particularly in Africa and Asia. There is extensive ethnographic evidence and also some very early historical descriptions of some of these systems. Many rely on planting nitrogen-fixing species together with crops such as wheat and maize, which demand high levels of nitrogen, but there are different permutations. Many systems are quite complex in their ecology, sometimes with over 100 species being planted together in one field (Altieri et al. 1987).

A key example is maize, which originated in the Americas. At least half the early colonists' and explorers' accounts describe the system of intercropping with maize, beans and squash, known to the American Indians as the Three Sisters (Doolittle 2000: 141). The maize grows first and provides a stalk for the beans to grow on. The beans are nitrogen fixers, taking nitrogen from the atmosphere and making it available in the soil for the maize (with the help of friendly nitrogen-fixing bacteria). The squashes have large leaves which cover the ground, reducing erosion by protecting the soil from rain splash (the destructive impact of the raindrops) and providing shade, thereby reducing evaporation from the soil and discouraging weeds. In addition, slightly toxic chemicals from the squash leaves are washed by rainfall into the soil, preventing weed growth but not harming the maize and beans (Doolittle 2000: 144).

Some of the most elaborate intercropping systems were developed in China. Agricultural treatises written in the Warring States period (475–221 BC) describe crop rotation, flood control, irrigation and manuring over 2000 years ago (Wittwer et al. 1987). An agricultural treatise written in the sixth century AD describes crop rotation and the benefits of planting legumes in advance of other crops (Wenhua 1993), which as we know adds nitrogen to the soil. A particularly efficient system was developed in the Guangdong Province, on the Zhujiang (Pearl River) Delta (Luo and Han 1990). The rice paddies double as fish ponds for grass carp, which eat only the weeds that grow in the paddies. Common carp and dace are kept in the paddies to eat the grass carp excrement, which would destroy the water quality, and the other fish waste settles to the bottom of the paddy. Periodically, the nitrogen-rich mud at the base of the paddy is collected and used to build fertile raised fields around the paddies, where mulberry trees are grown. The mulberry leaves are used to feed silkworms, and silkworm waste and mulberry leaves drop into the ponds and provide food for the fish. The Chinese traditions predating the Cultural Revolution are characterized by careful use and re-use of all resources, in systems which are positively elegant in their resourcefulness.

One of the interesting things about the early Chinese agricultural treatises is the emphasis on balance and sustainability, on working *with* nature instead of against it. The interaction of plants with one another (and with animals) is of great importance, and continues to be a significant element of organic farming today. Planting different strains of rice in the same field can reduce the spread of disease, and is a long-standing tradition in Asian countries (Capistrano and Marten 1986). It also increases the likelihood of a crop during environmental extremes, which some strains are able to withstand better than others. In Ethiopia it is common to grow three or four varieties of wheat together in one field, and often up to fifteen varieties (Tesemma 1991). In diversity is security.

Sustainable agriculture, hunger and poverty

GM companies and traditional agronomists argue that sustainable agriculture is a luxury in a world where people are starving (Fedoroff et al. 2010; Hamilton et al. 2005), yet there is widespread evidence that sustainable agriculture not only regenerates exhausted soil and polluted countryside, but that it *increases* yields. Sustainable methods that are introduced to regions where modern technology is unavailable have doubled and even tripled food production (Pearce 2001, 2002; Pretty 1998a: 84–7; Pretty 1998b; Scialabba and Hattam 2002), but the benefits are not limited to developing countries. Some regions have access to new technologies but are suffering from the ecological effects of pesticide use, while yields have reached a plateau. Replacing pesticides with natural predators, multi-cropping and other sustainable methods has increased yields in these areas by an average of 10 per cent (Pretty 1998b). The cost of fertilizers and pesticides is eliminated or cut, the soil microbes and biota – vital to soil structure and health – are unharmed, biodiversity is restored and farmers' health is improved.

Conclusions

A few years ago I gave a lecture in an agriculture department at a leading British university, where I described the rediscovery of ancient agricultural techniques and discussed how we can put some of these ideas back into practice. An elderly professor said to me, 'It's a nice idea, *dear*, but it's *pie in the sky*'. At that time, sustainable ancient technologies had already been researched and put back to work in Peru, Bolivia, Egypt, Tunisia, Yemen, Jordan and India, and research by the International Center for Agricultural Research in the Dry Areas (ICARDA) was investigating the re-introduction of water harvesting systems in Egypt, Iraq, Jordan, Libya, Morocco, Pakistan, Syria, Tunisia and Yemen (Oweis et al. 2004b). Meanwhile, the United Nations and many NGOs are supporting the use of indigenous technology, and engineers are promoting 'intermediate technology' which often relies on traditional methods (IAASTD 2009; Scialabba and Hattam 2002). The Green Revolution of the 1960s and 1970s was instrumental in raising food production in developing countries through new technology, but many countries missed out, and the environmental and health impacts have been substantial (Pretty 1998a: 57–8; Tilman 1998). Two major reports have recently argued that the New Green Revolution must be based on knowledge, rather than technology, and we need more equitable systems so that small subsistence farmers do not lose out (Evans 2009; IAASTD 2009).

The benefits of sustainable agriculture have been exhaustively researched (e.g. Pretty 2007), and the necessity of preserving our resources is obvious. What is perhaps not so obvious is that we already have the technology to live sustainably on our planet, to revitalize the countryside and to lift rural populations out of poverty. It is not 'pie in the sky' – on the contrary, it is already happening.

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