1.4 Organic farming and permaculture

1.4.1 Organic farming

Organic farming is a form of agriculture that relies on techniques such as crop rotation, green manure, compost, and biological pest control. Depending on whose definition is used, organic farming uses fertilizers and pesticides (which include herbicides, insecticides and fungicides) if they are considered natural (such as bone meal from animals or pyrethrin from flowers), but it excludes or strictly limits the use of various methods (including synthetic petrochemical fertilizers and pesticides; plant growth regulators such as hormones; antibiotic use in livestock; genetically modified organisms;[1] human sewage sludge; and nanomaterials.[2]) for reasons including sustainability, openness, independence, health, and safety.

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), an international umbrella organization for organic farming organizations established in 1972.[3] The USDA National Organic Standards Board (NOSB) definition as of April 1995 is:

“Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony."[4]

Since 1990 the market for organic food and other products has grown rapidly, reaching $63 billion worldwide in 2012.[5]:25 This demand has driven a similar increase in organically managed farmland which has grown over the years 2001-2011 at a compounding rate of 8.9% per annum.[6] As of 2011, approximately 37,000,000 hectares (91,000,000 acres) worldwide were farmed organically, representing approximately 0.9 percent of total world farmland (2009).[7]

History

Traditional farming (of many kinds) was the original type of agriculture, and has been practiced for thousands of years. Forest gardening, a traditional food production system which dates from prehistoric times, is thought to be the world's oldest and most resilient agroecosystem.[8]

Artificial fertilizers had been created during the 18th century, initially with superphosphates and then ammonia-based fertilizers mass-produced using the Haber-Bosch process developed during World War I. These early fertilizers were cheap, powerful, and easy to transport in bulk. Similar advances occurred in chemical pesticides in the 1940s, leading to the decade being referred to as the 'pesticide era'.[9] But these new agricultural techniques, while beneficial in the short term, had serious longer term side effects such as soil compaction, erosion, and declines in overall soil fertility, along with health concerns about toxic chemicals entering the food supply.[10]:10

Soil biology scientists began in the late 1800s and early 1900's to develop theories on how new advancements in biological science could be used in agriculture as a way to remedy these side effects, while still maintaining higher production. In Central Europe Rudolf Steiner, whose *Lectures on Agriculture* were published in 1925.[11][12][13]:[14] created biodynamic agriculture, an early version of what we now call organic agriculture.[15][16][17] The system was based on Steiner's philosophy of anthroposophy rather than on a solid grasp of science.[13]:17–19

In the late 1930s and early 1940s Sir Albert Howard and his wife Gabrielle Howard, both accomplished botanists, developed organic agriculture. The Howards were influenced by their experiences with traditional farming methods in India, biodynamic, and their formal scientific education.[11] Sir Albert Howard is widely considered to be the "father of organic farming", because he was the first to apply scientific knowledge and principles to these various traditional and more natural methods.[18]:45 In the United States another founder of organic agriculture was J.I. Rodale. In the 1940s he founded both a working organic farm for trials and experimentation, The Rodale Institute, and founded the Rodale Press to teach and advocate organic to the wider public. Further work was done by Lady Eve Balfour in the United Kingdom, and many others across the world.

Increasing environmental awareness in the general population in modern times has transformed the originally supply-driven organic movement to a demand-driven one. Premium prices and some government subsidies attracted farmers. In the developing world, many producers farm according to traditional methods which are comparable to organic farming but are not certified and may or may not include the latest scientific advancements in organic agriculture. In other cases, farmers in the developing world have converted to modern organic methods for economic reasons.[19]

Organic farming systems

There are several organic farming systems. Biodynamic farming is a comprehensive approach, with its own international governing body. The Do Nothing Farming method focuses on a minimum of mechanical cultivation and labor for grain crops. French intensive and biointensive, methods are well-suited to organic principles. Other examples of techniques are holistic management, permaculture, SRI and no-till farming (the last two which may be implemented in conventional or organic systems[20][21]).

Methods

Organic cultivation of mixed vegetables in Capay, California. Note the hedgerow in the background.

"An organic farm, properly speaking, is not one that uses certain methods and substances and avoids others; it is a farm whose structure is formed in imitation of the structure of a natural system that has the integrity, the independence and the benign dependence of an organism"

—Wendell Berry, "The Gift of Good Land"

Organic farming methods combine scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes. Organic farming methods are studied in the field of agroecology. While conventional agriculture uses synthetic pesticides and water-soluble synthetically purified fertilizers, organic farmers are restricted by regulations to using natural pesticides and fertilizers. The principal methods of organic farming include crop rotation, green manures and compost, biological pest control, and mechanical cultivation. These measures use the natural environment to enhance agricultural productivity: legumes are planted to fix nitrogen into the soil, natural insect predators are encouraged, crops are rotated to confuse pests and renew soil, and natural materials such as potassium bicarbonate[22] and mulches are used to control disease and weeds. Hardier plants are generated through plant breeding rather than genetic engineering.

While organic is fundamentally different from conventional because of the use of carbon based fertilizers compared with highly soluble synthetic based fertilizers and biological pest control instead of synthetic pesticides, organic farming and large-scale conventional farming are not entirely mutually exclusive. Many of the methods developed for organic agriculture have been borrowed by more conventional agriculture. For example, Integrated Pest Management is a multifaceted strategy that uses various organic methods of pest control whenever possible, but in conventional farming could include synthetic pesticides only as a last resort.[23]

Crop diversity

Crop diversity is a distinctive characteristic of organic farming. Conventional farming focuses on mass production of one crop in one location, a practice called monoculture. The science of agroecology has revealed the benefits of polyculture (multiple crops in the same space), which is often employed in organic farming.[24] Planting a variety of vegetable crops supports a wider range of beneficial insects, soil microorganisms, and other factors that add up to overall farm health. Crop diversity helps environments thrive and protect species from going extinct.[25]

Soil management

Organic farming relies heavily on the natural breakdown of organic matter, using techniques like green manure and composting, to replace nutrients taken from the soil by previous crops. This biological process, driven by microorganisms such as mycorrhiza, allows the natural production of nutrients in the soil throughout the growing season, and has been referred to as *feeding the soil to feed the plant.* Organic farming uses a variety of methods to improve soil fertility, including crop rotation, cover cropping, reduced tillage, and application of compost. By reducing tillage, soil is not inverted and exposed to air; less carbon is lost to the atmosphere resulting in more soil organic carbon. This has an added benefit of carbon sequestration which can reduce green house gases and aid in reversing climate change.

Plants need nitrogen, phosphorus, and potassium, as well as micronutrients and symbiotic relationships with fungi and other organisms to flourish, but getting enough nitrogen, and

particularly synchronization so that plants get enough nitrogen at the right time (when plants need it most), is a challenge for organic farmers.[26] Crop rotation and green manure ("cover crops") help to provide nitrogen through legumes (more precisely, the *Fabaceae* family) which fix nitrogen from the atmosphere through symbiosis with rhizobial bacteria. Intercropping, which is sometimes used for insect and disease control, can also increase soil nutrients, but the competition between the legume and the crop can be problematic and wider spacing between crop rows is required. Crop residues can be ploughed back into the soil, and different plants leave different amounts of nitrogen, potentially aiding synchronization.[26] Organic farmers also use animal manure, certain processed fertilizers such as seed meal and various mineral powders such as rock phosphate and greensand, a naturally occurring form of potash which provides potassium. Together these methods help to control erosion. In some cases pH may need to be amended. Natural pH amendments include lime and sulfur, but in the U.S. some compounds such as iron sulfate, aluminum sulfate, magnesium sulfate, and soluble boron products are allowed in organic farming.[27]:43

Mixed farms with both livestock and crops can operate as ley farms, whereby the land gathers fertility through growing nitrogen-fixing forage grasses such as white clover or alfalfa and grows cash crops or cereals when fertility is established. Farms without livestock ("stockless") may find it more difficult to maintain soil fertility, and may rely more on external inputs such as imported manure as well as grain legumes and green manures, although grain legumes may fix limited nitrogen because they are harvested. Horticultural farms growing fruits and vegetables which operate in protected conditions are often even more reliant upon external inputs.[26]

Biological research into soil and soil organisms has proven beneficial to organic farming. Varieties of bacteria and fungi break down chemicals, plant matter and animal waste into productive soil nutrients. In turn, they produce benefits of healthier yields and more productive soil for future crops.[28] Fields with less or no manure display significantly lower yields, due to decreased soil microbe community, providing a healthier, more arable soil system.[29]

Weed management

Organic weed management promotes weed suppression, rather than weed elimination, by enhancing crop competition and phytotoxic effects on weeds.[30] Organic farmers integrate cultural, biological, mechanical, physical and chemical tactics to manage weeds without synthetic herbicides.

Organic standards require rotation of annual crops,[31] meaning that a single crop cannot be grown in the same location without a different, intervening crop. Organic crop rotations frequently include weed-suppressive cover crops and crops with dissimilar life cycles to discourage weeds associated with a particular crop.[30] Research is ongoing to develop organic methods to promote the growth of natural microorganisms that suppress the growth or germination of common weeds.[32]

Other cultural practices used to enhance crop competitiveness and reduce weed pressure include selection of competitive crop varieties, high-density planting, tight row spacing, and late planting into warm soil to encourage rapid crop germination.[30]

Mechanical and physical weed control practices used on organic farms can be broadly grouped as:[33]

- Tillage – Turning the soil between crops to incorporate crop residues and soil amendments; remove existing weed growth and prepare a seedbed for planting; turning soil after seeding to kill weeds, including cultivation of row crops;
- Mowing and cutting – Removing top growth of weeds;
- Flame weeding and thermal weeding - Using heat to kill weeds; and
- Mulching – Blocking weed emergence with organic materials, plastic films, or landscape fabric.[34]

Some critics, citing work published in 1997 by David Pimentel of Cornell University,[35] which described an epidemic of topsoil erosion worldwide, have raised concerned that tillage contribute to the erosion epidemic.[36] The FAO and other organizations have advocated a "no-till" approach to both conventional and organic farming, and point out in particular that crop rotation techniques used in organic farming are excellent no-till approaches.[36][37] A study published in 2005 by Pimentel and colleagues[38] confirmed that "Crop rotations and cover cropping (green manure) typical of organic agriculture reduce soil erosion, pest problems, and pesticide use." Some naturally sourced chemicals are allowed for herbicidal use. These include certain formulations of acetic acid (concentrated vinegar), corn gluten meal, and essential oils. A few selective bioherbicides based on fungal pathogens have also been developed. At this time, however, organic herbicides and bioherbicides play a minor role in the organic weed control toolbox.[33]

Weeds can be controlled by grazing. For example, geese have been used successfully to weed a range of organic crops including cotton, strawberries, tobacco, and corn,[39] reviving the practice of keeping cotton patch geese, common in the southern U.S. before the 1950s. Similarly, some rice farmers introduce ducks and fish to wet paddy fields to eat both weeds and insects.[40]

Controlling other organisms

Chloroxylon is used for Pest Management in Organic Rice Cultivation in Chhattisgarh, India

Organisms aside from weeds that cause problems on organic farms include arthropods (e.g., insects, mites), nematodes, fungi and bacteria. Organic practices include, but are not limited to:

- encouraging predatory beneficial insects to control pests by serving them nursery plants and/or an alternative habitat, usually in a form of a shelterbelt, hedgerow, or beetle bank;
- encouraging beneficial microorganisms;

- rotating crops to different locations from year to year to interrupt pest reproduction cycles;
- planting companion crops and pest-repelling plants that discourage or divert pests;
- using row covers to protect crops during pest migration periods;
- using biologic herbicides or pesticides
- using no-till farming, and no-till farming techniques as false seedbeds[41]
- using sanitation to remove pest habitat;
- Using insect traps to monitor and control insect populations.
- Using physical barriers, such as row covers

Examples of predatory beneficial insects include minute pirate bugs, big-eyed bugs, and to a lesser extent ladybugs (which tend to fly away), all of which eat a wide range of pests. Lacewings are also effective, but tend to fly away. Praying mantis tend to move more slowly and eat less heavily. Parasitoid wasps tend to be effective for their selected prey, but like all small insects can be less effective outdoors because the wind controls their movement. Predatory mites are effective for controlling other mites.[27]:66–90

Naturally derived insecticides allowed for use on organic farms use include *Bacillus thuringiensis* (a bacterial toxin), pyrethrum (a chrysanthemum extract), spinosad (a bacterial metabolite), neem (a tree extract) and rotenone (a legume root extract). Fewer than 10% of organic farmers use these pesticides regularly; one survey found that only 5.3% of vegetable growers in California use rotenone while 1.7% use pyrethrum.[42]:26 These pesticides are not always more safe or environmentally friendly than synthetic pesticides and can cause harm.[27]:92 The main criterion for organic pesticides is that they are naturally derived, and some naturally derived substances have been controversial. Controversial natural pesticides include rotenone, copper, nicotine sulfate, and pyrethrums[43][44] Rotenone and pyrethrum are particularly controversial because they work by attacking the nervous system, like most conventional insecticides. Rotenone is extremely toxic to fish[45] and can induce symptoms resembling Parkinson's disease in mammals.[46][47] Although pyrethrum (natural pyrethrins) is more effective against insects when used with piperonyl butoxide (which retards degradation of the pyrethrins),[48] organic standards generally do not permit use of the latter substance.[49][50][51]

Naturally derived fungicides allowed for use on organic farms include the bacteria *Bacillus subtilis* and *Bacillus pumilus*; and the fungus *Trichoderma harzianum*. These are mainly effective for diseases affecting roots. Compost tea contains a mix of beneficial microbes, which may attack or out-compete certain plant pathogens,[52] but variability among formulations and preparation methods may contribute to inconsistent results or even dangerous growth of toxic microbes in compost teas.[53]

Some naturally derived pesticides are not allowed for use on organic farms. These include nicotine sulfate, arsenic, and strychnine.[54]

Synthetic pesticides allowed for use on organic farms include insecticidal soaps and horticultural oils for insect management; and Bordeaux mixture, copper hydroxide and sodium bicarbonate for managing fungi.[54] Copper sulfate and Bordeaux mixture (copper sulfate plus lime), approved for organic use in various jurisdictions,[49][50][54] can be more environmentally problematic than some synthetic fungicides dissallowed in organic farming[55][56] Similar concerns apply to copper hydroxide. Repeated application of copper sulfate or copper hydroxide as a fungicide may eventually result in copper accumulation to

toxic levels in soil,[57] and admonitions to avoid excessive accumulations of copper in soil appear in various organic standards and elsewhere. Environmental concerns for several kinds of biota arise at average rates of use of such substances for some crops.[58] In the European Union, where replacement of copper-based fungicides in organic agriculture is a policy priority,[59] research is seeking alternatives for organic production.[60]

Livestock

For livestock like these healthy cows vaccines play an important part in animal health since antibiotic therapy is prohibited in organic farming

Raising livestock and poultry, for meat, dairy and eggs, is another traditional, farming activity that complements growing. Organic farms attempt to provide animals with "natural" living conditions and feed. While the USDA does not require any animal welfare requirements be met for a product to be marked as organic, this is a variance from older organic farming practices.[61]

Also, horses and cattle used to be a basic farm feature that provided labor, for hauling and plowing, fertility, through recycling of manure, and fuel, in the form of food for farmers and other animals. While today, small growing operations often do not include livestock, domesticated animals are a desirable part of the organic farming equation, especially for true sustainability, the ability of a farm to function as a self-renewing unit.

Genetic modification

A key characteristic of organic farming is the rejection of genetically engineered plants and animals. On October 19, 1998, participants at IFOAM's 12th Scientific Conference issued the Mar del Plata Declaration, where more than 600 delegates from over 60 countries voted unanimously to exclude the use of genetically modified organisms in food production and agriculture.

Although opposition to the use of any transgenic technologies in organic farming is strong, agricultural researchers Luis Herrera-Estrella and Ariel Alvarez-Morales continue to advocate integration of transgenic technologies into organic farming as the optimal means to sustainable agriculture, particularly in the developing world,[62] as does author and scientist Pamela Ronald, who views this kind of biotechnology as being consistent with organic principles.[63]

Although GMOs are excluded from organic farming, there is concern that the pollen from genetically modified crops is increasingly penetrating organic and heirloom seed stocks, making it difficult, if not impossible, to keep these genomes from entering the organic food

supply. Differing regulations among countries limits the availability of GMOs to certain countries, as described in the article on regulation of the release of genetic modified organisms.

Standards

Standards regulate production methods and in some cases final output for organic agriculture. Standards may be voluntary or legislated. As early as the 1970s private associations certified organic producers. In the 1980s, governments began to produce organic production guidelines. In the 1990s, a trend toward legislated standards began, most notably with the 1991 EU-Eco-regulation developed for European Union,[64] which set standards for 12 countries, and a 1993 UK program. The EU's program was followed by a Japanese program in 2001, and in 2002 the U.S. created the National Organic Program (NOP).[65] As of 2007 over 60 countries regulate organic farming (IFOAM 2007:11). In 2005 IFOAM created the Principles of Organic Agriculture, an international guideline for certification criteria.[66] Typically the agencies accredit certification groups rather than individual farms.

Organic production materials used in and foods are tested independently by the Organic Materials Review Institute.[67]

Composting

Under USDA organic standards, manure must be subjected to proper thermophilic composting and allowed to reach a sterilizing temperature. If raw animal manure is used, 120 days must pass before the crop is harvested if the final product comes into direct contact with the soil. For products which do not come into direct contact with soil, 90 days must pass prior to harvest.[68]

Economics

The economics of organic farming, a subfield of agricultural economics, encompasses the entire process and effects of organic farming in terms of human society, including social costs, opportunity costs, unintended consequences, information asymmetries, and economies of scale. Although the scope of economics is broad, agricultural economics tends to focus on maximizing yields and efficiency at the farm level. Economics takes an anthropocentric approach to the value of the natural world: biodiversity, for example, is considered beneficial only to the extent that it is valued by people and increases profits. Some entities such as the European Union subsidize organic farming, in large part because these countries want to account for the externalities of reduced water use, reduced water contamination, reduced soil erosion, reduced carbon emissions, increased biodiversity, and assorted other benefits that result from organic farming.[43]

Traditional organic farming is labor and knowledge-intensive whereas conventional farming is capital-intensive, requiring more energy and manufactured inputs.[69] Organic farmers in California have cited marketing as their greatest obstacle.[70]

Geographic producer distribution

The markets for organic products are strongest in North America and Europe, which as of 2001 are estimated to have $6 and $8 billion respectively of the $20 billion global market.[42]

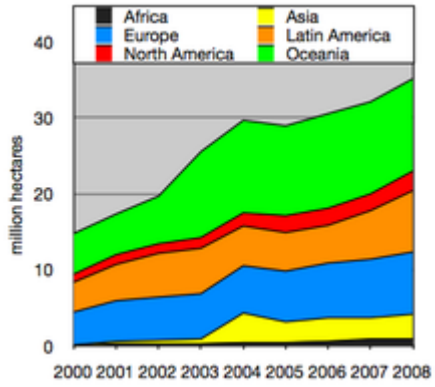
As of 2007 Australasia has 39% of the total organic farmland, including Australia's 1,180,000 hectares (2,900,000 acres) but 97 percent of this land is sprawling rangeland (2007:35). US sales are 20x as much.[42]:7 Europe farms 23 percent of global organic farmland (6.9 million hectares), followed by Latin America with 19 percent (5.8 million hectares). Asia has 9.5 percent while North America has 7.2 percent. Africa has 3 percent.[71]

Besides Australia, the countries with the most organic farmland are Argentina (3.1 million hectares), China (2.3 million hectares), and the United States (1.6 million hectares). Much of Argentina's organic farmland is pasture, like that of Australia (2007:42). Spain, Germany, Brazil (the world's largest agricultural exporter), Uruguay, and the UK follow the United States in the amount of organic land (2007:26).

In the European Union (EU25) 3.9% of the total utilized agricultural area was used for organic production in 2005. The countries with the highest proportion of organic land were Austria (11%) and Italy (8.4), followed by the Czech Republic and Greece (both 7.2%). The lowest figures were shown for Malta (0.1%), Poland (0.6%) and Ireland (0.8%).[72][73] In 2009, the proportion of organic land in the EU grew to 4.7%. The countries with highest share of agricultural land were Liechtenstein (26.9%), Austria (18.5%) and Sweden (12.6%).[74] 16% of all farmers in Austria produced organically in 2010. By the same year the proportion of organic land increased to 20%.:[75] In 2005 168,000 ha of land in Poland was under organic management.[76] In 2010 100,000 ha of land were under organic management in Romania, representing 1% of the total utilized agricultural area. 70%-80% of the local organic production, amounting to 100 million Euros in 2010, is exported. The organic products market grew to 50 million Euros in 2010.[77]

After the collapse of the Soviet Union in 1991, agricultural inputs that had previously been purchased from Eastern bloc countries were no longer available in Cuba, and many Cuban farms converted to organic methods out of necessity.[78] Consequently, organic agriculture is a mainstream practice in Cuba, while it remains an alternative practice in most other countries. Although some products called organic in Cuba would not satisfy certification requirements in other countries (crops may be genetically modified, for example[79][80]), Cuba exports organic citrus and citrus juices to EU markets that meet EU organic standards. Cuba's forced conversion to organic methods may position the country to be a global supplier of organic products.[81]

Growth



Organic farmland by world region (2000-2008)

As of 2001, the estimated market value of certified organic products was estimated to be $20 billion. By 2002 this was $23 billion and by 2007 more than $46 billion.[7] By 2012 the market had reached $63 billion worldwide.[5]:25

Europe (2011: 10.6 million hectares, which is 5.4 percent of Europe's farmland and an increase of 6% from the prior year; Europe has 29% of the world's organic agricultural land) and North America (2011: 2.8 million hectares, 7.5% of the world's organic agricultural land) have experienced strong growth in organic farmland.[5]:26 In the EU it grew by 21% in the period 2005 to 2008.[82] However, this growth has occurred under different conditions. While the European Union has shifted agricultural subsidies to organic farmers due to perceived environmental benefits, the United States has not,[83] continuing to subsidize some but not all traditional commercial crops, such as corn and sugar. As a result of this policy difference, as of 2008 4.1% percent of European Union farmland was organically managed compared to the 0.6 percent in the U.S.[7]

As of 2012 the country with the most organic land was Australia (12 million hectares), followed by Argentina (3.8 million hectares), and the United States (1.9 million hectares).[5]:26

Productivity

Studies comparing yields have had mixed results.[84]

A meta-analysis study published in 2012 suggests farmers should take a hybrid approach to producing enough food for humans while preserving the environment.[85]

A study published in 1990 made "two hundred and five comparisons ... of yields from organic and conventional farming systems..... Data from 26 crops and two animal products, in the form of the ratio of organic to conventional yields, were normally distributed with a mean of 0.91, a standard deviation of 0.24 and a modal value between 0.8 and 0.9. More than one-half of the comparisons of milk production and bean yields had ratios greater than 1.0, i.e. higher yields from organic than conventional systems. There was no evidence to show that the organic systems had any effect on year-to-year variability in yield, either climate-induced or caused by any transitional or conversion effects." The study also discussed procedural difficulties in comparing the productivity of organic with other farming systems.[86]

A US survey published in 2001 analyzed 150 growing seasons of data on grain and soybean crops and concluded that organic yields were 95-100% of conventional yields.[84]

A study spanning two decades was published in 2002 and found a 20% smaller yield from organic farms using 50% less fertilizer, 97% less pesticide, and energy input was 34% to 53% lower.[87]

A 2003 study found that during drought years, organic farms can have yields 20-40% higher than conventional farms.[88] Organic farms are more profitable in the drier states of the United States, likely due to their superior drought performance.[89]

Organic farms survive hurricane damage much better, retaining 20 to 40% more topsoil and smaller economic losses at highly significant levels than their neighbors.[90]

A study published in 2005 compared conventional cropping, organic animal-based cropping, and organic legume-based cropping on a test farm at the Rodale Institute over 22 years.[91] The study found that "the crop yields for corn and soybeans were similar in the organic animal, organic legume, and conventional farming systems". It also found that "significantly less fossil energy was expended to produce corn in the Rodale Institute's organic animal and organic legume systems than in the conventional production system. There was little difference in energy input between the different treatments for producing soybeans. In the organic systems, synthetic fertilizers and pesticides were generally not used". As of 2013 the Rodale study was ongoing[92] and a thirty year anniversary report was published by Rodale in 2012.[93]

A 2007 study[94] compiling research from 293 different comparisons into a single study to assess the overall efficiency of the two agricultural systems has concluded that "organic methods could produce enough food on a global per capita basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base." The researchers also found that while in developed countries, organic systems on average produce 92% of the yield produced by conventional agriculture, organic systems produce 80% more than conventional farms in developing countries, because the materials needed for organic farming are more accessible than synthetic farming materials to farmers in some poor countries. This study was strongly contested by another study published in 2008 which stated, and was entitled, "Organic agriculture cannot feed the world"[95] and said that the 2007 came up with "a major overestimation of the productivity of OA" "because data are misinterpreted and calculations accordingly are erroneous."

Another study published in 1999 from the Danish Environmental Protection Agency found that, area-for-area, organic farms of potatoes, sugar beet and seed grass produce as little as half the output of conventional farming.[96] Michael Pollan, author of *The Omnivore's Dilemma*, responds to this by pointing out that the average yield of world agriculture is substantially lower than modern sustainable farming yields. Bringing average world yields up to modern organic levels could increase the world's food supply by 50%.[97]

Profitability

The decreased cost of synthetic fertilizer and pesticide inputs, along with the higher prices that consumers pay for organic produce, contribute to increased profits. Organic farms have been consistently found to be as or more profitable than conventional farms. Without the price premium, profitability is mixed.[42]:11 Organic production was more profitable in Wisconsin, given price premiums.[98]

For markets and supermarkets organic food is profitable as well, and is generally even sold at significantly higher rates than non-organic food[99]

However, when the buyer compares prices and buys consciously, organic food is not always more expensive for the buyer than non-organic food. For example, in 2000, Phillipe Renard made his restaurant to switch to use 85% organic food, without increasing the cost for the clients.[100] In the documentary "Architects for Change", he also stated that since 2000, the cost of organic products has come down even more, and at present, it is no longer a problem to attain organic products at a price comparative to products of non-organic agriculture.[101]

Energy efficiency

A study of the sustainability of apple production systems showed that in comparing a conventional farming system to an organic method of farming, the organic system in this case is more energy efficient.[102] A more comprehensive study compared efficiency of agriculture for products such as grain, roughage crops, and animal husbandry. While the study did not investigate specific additional requirements of arable land or numbers of farm laborers to produce total yields for organic farming vs. conventional farming, leaving open the question of overall capacity of organic farming to meet current and future agricultural needs, it concluded that organic farming had a higher yield per unit of energy over multiple crops and for livestock. However, conventional farming had higher total yield.[103] Conversely, another study noted that organic wheat and corn production was more energy efficient than conventional methods while organic apple and potato production was less energy efficient than conventional methods.[104]

A study done with apple orchards in the state of Washington found that organic orchards found to be at least 7% more energy efficient.[102]

Sales and marketing

Most sales are concentrated in developed nations. These products are what economists call credence goods in that they rely on uncertain certification. Interest in organic products dropped between 2006 and 2008, and 42% of Americans polled don't trust organic produce.[105] 69% of Americans claim to occasionally buy organic products, down from 73% in 2005. One theory was that consumers were substituting "local" produce for "organic" produce.[106]

Distributors

In the United States, 75% of organic farms are smaller than 2.5 hectares. In California 2% of the farms account for over half of sales.[42]:4 Small farms join together in cooperatives such as Organic Valley, In. to market their goods more effectively.

Most small cooperative distributors have merged or were acquired by large multinationals such as General Mills, Heinz, ConAgra, Kellogg, and others. In 1982 there were 28 consumer cooperative distributors, but as of 2007 only 3 remained.[107] This consolidation has raised concerns among consumers and journalists of potential fraud and degradation in standards. Most sell their organic products through subsidiaries, under other labels.[108]

Organic foods also can be a niche in developing nations. It would provide more money and a better opportunity to compete internationally with the huge distributors. Organic prices are much more stable than conventional foods, and the small farms can still compete and have similar prices with the much larger farms that usually take all of the profits.[109]

Farmers markets

Price premiums are important for the profitability of small organic farmers. Farmers selling directly to consumers at farmers' markets have continued to achieve these higher returns. In the United States the number of farmers' markets tripled from 1,755 in 1994 to 5,274 in 2009.[110]

Labor and employment

Organic production is more labor-intensive than conventional production.[111] On the one hand, this increased labor cost is one factor that makes organic food more expensive.[111] On the other hand, the increased need for labor may be seen as an "employment dividend" of organic farming, providing more jobs per unit area than conventional systems.[112]

World's food security

In 2007 the United Nations Food and Agriculture Organization (FAO) said that organic agriculture often leads to higher prices and hence a better income for farmers, so it should be promoted. However, FAO stressed that by organic farming one could not feed current mankind, even less a bigger future population. Both data and models showed then that organic farming was far from sufficient. Therefore chemical fertilizers were needed to avoid hunger.[113] Other analysis by many agribusiness executives, agricultural and ecological scientists, and international agriculture experts revealed the opinion that organic farming would not only increase the world's food supply, but might be the only way to eradicate hunger.[114]

FAO stressed that fertilizers and other chemical inputs can much increase the production, particularly in Africa where fertilizers are currently used 90% less than in Asia.[113] For example, in Malawi the yield has been boosted using seeds and fertilizers.[113] FAO also calls for using biotechnology, as it can help smallholder farmers to improve their income and food security.[115]

Also NEPAD, development organization of African governments, announced that feeding Africans and preventing malnutrition requires fertilizers and enhanced seeds.[116]

According to a more recent study in ScienceDigest, organic best management practices shows an average yield only 13% less than conventional.[117] In the world's poorer nations where most of the world's hungry live, and where conventional agriculture's expensive inputs are not affordable by the majority of farmers, adopting organic management actually increases yields 93% on average, and could be an important part of increased food security.[114][118]

Capacity building in developing countries

Organic agriculture can contribute to ecologically sustainable, socio-economic development, especially in poorer countries.[119] The application of organic principles enables employment of local resources (e.g., local seed varieties, manure, etc.) and therefore cost-effectiveness. Local and international markets for organic products show tremendous growth prospects and offer creative producers and exporters excellent opportunities to improve their income and living conditions.

Organic agriculture is knowledge intensive. Globally, capacity building efforts are underway, including localized training material, to limited effect. As of 2007, the International Federation of Organic Agriculture Movements hosted more than 170 free manuals and 75 training opportunities online.

In 2008 the United Nations Environmental Programme (UNEP) and the United Nations Conference on Trade and Development (UNCTAD) stated that "organic agriculture can be more conducive to food security in Africa than most conventional production systems, and that it is more likely to be sustainable in the long-term"[120] and that "yields had more than doubled where organic, or near-organic practices had been used" and that soil fertility and drought resistance improved.[121]

Organic Agriculture and the Millennium Development Goals (MDGs)

The value of organic agriculture (OA)in the achievement of the MDGs particularly in poverty reduction efforts in the face of climate change can be shown in its contribution to both income and non-income aspects of the MDGs. A series of case studies conducted by the Asian Development Bank Institute (ADBI) in Tokyo showed that OA contributes to both income and non-income aspects of the MDGs in all the study areas in selected Asian countries. OA's outcomes on MDGs include contributions to the alleviation of poverty by way of higher incomes, improved farmers' health owing to less chemical exposure, integration of sustainable principles into rural development policies, improvement of access to safe water and sanitation, and expansion of global partnership for development.[122]

A related ADBI study on OA estimates costs of OA programs and sets them in the context of the costs of attaining the MDGs. The results show considerable variation across the case studies, suggesting that there is no clear structure to the costs of adopting OA. Costs depend on the efficiency with which the OA adoption programs are run. The lowest cost programs were more than ten times less expensive than the highest cost ones. A further analysis of the gains resulting from OA adoption reveals that the costs per person taken out of poverty was much lower than the estimates of the World Bank,[123] based on income growth in general or based on the detailed costs of meeting some of the more quantifiable MDGs (e.g., education, health, and environment).[124]

Externalities

Agriculture imposes negative externalities (uncompensated costs) upon society through land and other resource use, biodiversity loss, erosion, pesticides, nutrient runoff, water usage, subsidy payments and assorted other problems. Positive externalities include self-reliance, entrepreneurship, respect for nature, and air quality. Organic methods reduce some of these costs.[125] In 2000 uncompensated costs for 1996 reached 2,343 million British pounds or 208 pounds per hectare.[126] A study of practices in the USA published in 2005 concluded that cropland costs the economy approximately 5 to 16 billion dollars ($30 to $96 per hectare), while livestock production costs 714 million dollars.[127] Both studies recommended reducing externalities. The 2000 review included reported pesticide poisonings but did not include speculative chronic health effects of pesticides, and the 2004 review relied on a 1992 estimate of the total impact of pesticides.

It has been proposed that organic agriculture can reduce the level of some negative externalities from (conventional) agriculture. Whether the benefits are private or public depends upon the division of property rights.[128]

Several surveys and studies have attempted to examine and compare conventional and organic systems of farming and have found that organic techniques, while not without harm, are less damaging than conventional ones because they reduce levels of biodiversity less than

conventional systems do and use less energy and produce less waste when calculated per unit area.[129][130]

A 2003 to 2005 investigation by the Cranfield University for the Department for Environment Food and Rural Affairs in the UK found that it is difficult to compare the Global Warming Potential (GWP), acidification and eutrophication emissions but "Organic production often results in increased burdens, from factors such as N leaching and N2O emissions", even though primary energy use was less for most organic products. N20 is always the largest GWP contributor except in tomatoes. However, "organic tomatoes always incur more burdens (except pesticide use)". Some emissions were lower "per area", but organic farming always required 65 to 200% more field area than non-organic farming. The numbers were highest for bread wheat (200+ % more) and potatoes (160% more).[131][132]

The situation was shown dramatically in a comparison of a modern dairy farm in Wisconsin with one in New Zealand in which the animals grazed extensively.[133] Using total farm emissions per kg milk produced as a parameter, the researchers showed that production of methane from belching was higher in the New Zealand farm, while carbon dioxide production was higher in the Wisconsin farm. Output of nitrous oxide, a gas with an estimated global warming potential 310 times that of carbon dioxide was also higher in the New Zealand farm. Methane from manure handling was similar in the two types of farm. The explanation for the finding relates to the different diets used on these farms, being based more completely on forage (and hence more fibrous) in New Zealand and containing less concentrate than in Wisconsin. Fibrous diets promote a higher proportion of acetate in the gut of ruminant animals, resulting in a higher production of methane that has to be released by belching. When cattle are given a diet containing some concentrates (such as corn and soybean meal) in addition to grass and silage, the pattern of ruminal fermentation alters from acetate to mainly propionate. As a result methane production is reduced. Capper et al. compared the environmental impact of US dairy production in 1944 and 2007.[134] They calculated that the carbon “footprint” per billion kg of milk produced in 2007 was 37 percent that of equivalent milk production in 1944.

Environmental impact and emissions

Researchers at Oxford university analyzed 71 peer-reviewed studies and observed that organic products are sometimes worse for the environment.[135] Organic milk, cereals, and pork generated higher greenhouse gas emissions per product than conventional ones but organic beef and olives had lower emissions in most studies.[135] Usually organic products required less energy, but more land.[135] Nitrogen leaching, nitrous oxide emissions, ammonia emissions, eutrophication potential and acidification potential were higher for organic products, however organic methods had less nutrient losses (nitrogen leaching, nitrous oxide emissions and ammonia emissions) per unit of field area.[136] Other differences were not significant.[136] The researchers concluded "Most of the studies that compared biodiversity in organic and conventional farming demonstrated lower environmental impacts from organic farming." The researchers believe that the ideal outcome would be to develop new systems that consider both the environment, including setting land aside for wildlife and sustainable forestry, and the development of ways to produce the highest yields possible using both conventional and organic methods.[135][137]

Proponents of organic farming have claimed that organic agriculture emphasizes closed nutrient cycles, biodiversity, and effective soil management providing the capacity to

mitigate and even reverse the effects of climate change[138] and that organic agriculture can decrease fossil fuel emissions.[139]

Critics of organic farming methods believe that the increased land needed to farm organic food could potentially destroy the rainforests and wipe out many ecosystems.[140][141]

Nutrient leaching

According to the meta-analysis of 71 studies, nitrogen leaching, nitrous oxide emissions, ammonia emissions, eutrophication potential and acidification potential were higher for organic products,[136] although in one study "nitrate leaching was 4.4-5.6 times higher in conventional plots than organic plots".[142] Excess nutrients in lakes, rivers, and groundwater can cause algal blooms, eutrophication, and subsequent dead zones. In addition, nitrates are harmful to aquatic organisms by themselves.[143]

Land use

The Oxford meta-analysis of 71 studies proved that organic farming requires 84% more land, mainly due to lack of nutrients but sometimes due to weeds, diseases or pests, lower yielding animals and land required for fertility building crops.[136] While organic farming does not necessarily save land for wildlife habitats and forestry in all cases,[135] the most modern breakthroughs in organic are addressing these issues with success.[144][145][146]

Professor Wolfgang Branscheid says that organic animal production is not good for the environment, because organic chicken requires doubly as much land as conventional one and organic pork a quarter more.[147] According to a calculation by Hudson Institute, organic beef requires triply as much land.[148] On the other hand certain organic methods of animal husbandry have been shown to restore desertified, marginal, and/or otherwise unavailable land to agricultural productivity and wildlife.[149][150] or by getting both forage and cash crop production from the same fields simultaneously, reduce net land use.[151]

In England organic farming yields 55% of normal yields.[152][153] While in other regions of the world, organic methods have started producing record yields.[154][155]

Pesticides

A sign outside of an organic apple orchard in Pateros, Washington reminding orchardists not to spray pesticides on these trees.

Unlike conventional farms, most organic farms largely avoid synthetic pesticides[156] Some pesticides damage the environment or with direct exposure, human health. Children may be more at risk than adults from direct exposure, as the toxicity of pesticides is frequently different in children and adults.[157]

The five main pesticides used in organic farming are Bt (a bacterial toxin), pyrethrin, rotenone,[158] copper and sulphur.[159] "Fewer than 10% of organic farmers use botanical insecticides on a regular basis, 12% use sulfur, and 7% use copper-based compounds." [42]:26 Reduction and elimination of chemical pesticide use is technically challenging.[160] Organic pesticides often complement other pest control strategies.

Ecological concerns primarily focus around pesticide use, as 16% of the world's pesticides are used in the production of cotton.[161]

Runoff is one of the most damaging effects of pesticide use. The USDA Natural Resources Conservation Service tracks the environmental effects of water contamination and concluded, "the Nation's pesticide policies during the last twenty six years have succeeded in reducing overall environmental risk, in spite of slight increases in area planted and weight of pesticides applied. Nevertheless, there are still areas of the country where there is no evidence of progress, and areas where risk levels for protection of drinking water, fish, algae and crustaceans remain high".[162][163]

Food quality and safety

The weight of the available scientific evidence has not shown a consistent and significant difference between organic and more conventionally grown food in terms of safety,[164][165][166][167][168] or nutritional value.[164][166][168][169] In 2009 a review of all the relevant research comparing organic to conventionally grown foods was carried out by the United Kingdom's Food Standards Agency which concluded:

No evidence of a difference in content of nutrients and other substances between organically and conventionally produced crops and livestock products was detected for the majority of nutrients assessed in this review suggesting that organically and conventionally produced crops and livestock products are broadly comparable in their nutrient content... There is no good evidence that increased dietary intake, of the nutrients identified in this review to be present in larger amounts in organically than in conventionally produced crops and livestock products, would be of benefit to individuals consuming a normal varied diet, and it is therefore unlikely that these differences in nutrient content are relevant to consumer health.[170]

A 2009 review of potential health effects conducted for the UK Food Standards Agency analysed eleven articles, concluding, "because of the limited and highly variable data available, and concerns over the reliability of some reported findings, there is currently no evidence of a health benefit from consuming organic compared to conventionally produced foodstuffs. It should be noted that this conclusion relates to the evidence base currently available on the nutrient content of foodstuffs, which contains limitations in the design and in the comparability of studies."[171]

Individual studies have considered a variety of possible impacts, including pesticide residues.[165] Pesticide residues present a second channel for health effects.[172][173] Comments

include, "Organic fruits and vegetables can be expected to contain fewer agrochemical residues than conventionally grown alternatives; yet, "the significance of this difference is questionable".[165]

Nitrate concentrations may be less, but the health impact of nitrates is debated.[174] Lack of data has limited research into the health effects of natural plant pesticides and bacterial pathogens.[165]

The higher cost of organic food (ranging from 45 to 200%) could inhibit consumption of the recommended 5 servings per day of vegetables and fruits, which improve health and reduce cancer regardless of their source.[165]

Soil conservation

Supporters claim that organically managed soil has a higher quality[175] and higher water retention. This may help increase yields for organic farms in drought years. Organic farming can build up soil organic matter better than conventional no-till farming, which suggests long-term yield benefits from organic farming.[176] An 18-year study of organic methods on nutrient-depleted soil, concluded that conventional methods were superior for soil fertility and yield for nutrient-depleted soils in cold-temperate climates, arguing that much of the benefits from organic farming are derived from imported materials which could not be regarded as "self-sustaining".[177]

In *Dirt: The Erosion of Civilizations*, geomorphologist David Montgomery outlines a coming crisis from soil erosion. Agriculture relies on roughly one meter of topsoil, and that is being depleted ten times faster than it is being replaced.[178] No-till farming, which some claim depends upon pesticides, is one way to minimize erosion. However, a recent study by the USDA's Agricultural Research Service has found that manure applications in tilled organic farming are better at building up the soil than no-till.[139][179][180]

Biodiversity

A wide range of organisms benefit from organic farming, but it is unclear whether organic methods confer greater benefits than conventional integrated agri-environmental programs.[181] Nearly all non-crop, naturally occurring species observed in comparative farm land practice studies show a preference for organic farming both by abundance and diversity.[181][182] An average of 30% more species inhabit organic farms.[183] Birds, butterflies, soil microbes, beetles, earthworms,[184] spiders, vegetation, and mammals are particularly affected. Lack of herbicides and pesticides improve biodiversity fitness and population density.[182] Many weed species attract beneficial insects that improve soil qualities and forage on weed pests.[185] Soil-bound organisms often benefit because of increased bacteria populations due to natural fertilizer such as manure, while experiencing reduced intake of herbicides and pesticides.[181] Increased biodiversity, especially from beneficial soil microbes and mycorrhizae have been proposed as an explanation for the high yields experienced by some organic plots, especially in light of the differences seen in a 21-year comparison of organic and control fields.[29]

Biodiversity from organic farming provides capital to humans. Species found in organic farms enhance sustainability by reducing human input (e.g., fertilizers, pesticides).[186]

Proponents of organic farming

"Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved..."

— International Federation of Organic Agriculture Movements[187]

Critical analysis

Norman Borlaug (father of the "Green Revolution" and a Nobel Peace Prize laureate), Prof A. Trewavas and other critics contested the notion that organic agricultural systems are more friendly to the environment and more sustainable than conventional farming systems. Borlaug asserts that organic farming practices can at most feed 4 billion people, after expanding cropland dramatically and destroying ecosystems in the process.[188][189][190][191] Borlaug and his co-authors advocated using organic matter in addition to inorganic fertilizers in soil fertility management, but opposed advocating only organic agriculture for the developing world.[192] The Danish Environmental Protection Agency estimated that phasing out all pesticides would result in an overall yield reduction of about 25%. Environmental and health effects were assumed but hard to assess.[193]

One study claims that organic agriculture could feed the entire global population, somewhat more than 6 billion people. It states that organic farms have lower yields than their conventional counterparts in developed countries (92%) but higher than their low-intensity counterparts in developing countries (180%), attributing this to lower adoption of fertilizers and pesticides in the developing world compared to the intensive farming of the developed world.[194] However, concerns have been expressed about that study's selection, characterization and interpretation of data, and its assumptions and analytical methods, casting doubt on several of its conclusions.[13]:39–72[95][195][196][197]

The Centers for Disease Control repudiated a claim by Dennis Avery of the Hudson Institute, that the risk of E. coli infection was eight times higher when eating organic food. (Avery had cited CDC as a source.) Avery had included problems stemming from non-organic unpasteurized juice in his calculations.[198][199][200] Epidemiologists traced the 2011 E. coli O104:H4 outbreak – which caused over 3,900 cases and 52 deaths – to an organic farm in Bienenbüttel in Germany.[201][202]

A long-term field study comparing organic/conventional agriculture carried out over 21 years in Switzerland concluded that "Crop yields of the organic systems averaged over 21 experimental years at 80% of the conventional ones. The fertilizer input, however, was 34 – 51% lower, indicating an efficient production. The organic farming systems used 20 – 56% less energy to produce a crop unit and per land area this difference was 36 – 53%. In spite of the considerably lower pesticide input the quality of organic products was hardly discernible from conventional analytically and even came off better in food preference trials and picture creating methods"[203]

Urs Niggli, director of the FiBL Institute, contends that a global campaign against organic farming[204] derives mostly from Alex Avery's book *The Truth About Organic Farming*.[198]

1.4.2 Permaculture

Permaculture is a branch of ecological design, ecological engineering, environmental design, construction and integrated water resources management that develops sustainable architecture, regenerative and self-maintained habitat and agricultural systems modeled from natural ecosystems.[1][2] The term permaculture (as a systematic method) was first coined by Australians Bill Mollison and David Holmgren in 1978. The word *permaculture* originally referred to "permanent agriculture" [3] but was expanded to stand also for "permanent culture," as it was seen that social aspects were integral to a truly sustainable system as inspired by Masanobu Fukuoka's natural farming philosophy.

Permaculture is a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labor; and of looking at plants and animals in all their functions, rather than treating any area as a single product system.

—Bill Mollison, [4]

Contents

History

In 1929, Joseph Russell Smith took up an antecedent term as the subtitle for *Tree Crops: A Permanent Agriculture*, a book in which he summed up his long experience experimenting with fruits and nuts as crops for human food and animal feed.[5] Smith saw the world as an inter-related whole and suggested mixed systems of trees and crops underneath. This book inspired many individuals intent on making agriculture more sustainable, such as Toyohiko Kagawa who pioneered forest farming in Japan in the 1930s.[6]

The definition of permanent agriculture as that which can be sustained indefinitely was supported by Australian P. A. Yeomans in his 1973 book *Water for Every Farm*. Yeoman introduced an observation-based approach to land use in Australia in the 1940s; and the keyline design as a way of managing the supply and distribution of water in the 1950s.

Stewart Brand's works were an early influence noted by Holmgren.[7] Other early influences include Ruth Stout and Esther Deans, who pioneered "no-dig gardening methods", and Masanobu Fukuoka who, in the late 1930s in Japan, began advocating no-till orchards, gardens and natural farming.[8]

The first recorded modern application of permaculture concepts as a systematic method was possibly by Austrian farmer Sepp Holzer in the 1960s.

Core tenets

The core tenets of permaculture are:[9][10][11]

- ***Care for the earth***: Provision for all life systems to continue and multiply. This is the first principle, because without a healthy earth, humans cannot flourish.
- ***Care for the people***: Provision for people to access those resources necessary for their existence.
- ***Return of surplus***: Reinvesting surpluses back into the system to provide for the first two ethics. This includes returning waste back into the system to recycle into usefulness.[12]

Permaculture design emphasizes patterns of landscape, function, and species assemblies. It determines where these elements should be placed so they can provide maximum benefit to the local environment. The central concept of permaculture is maximizing useful connections between components and synergy of the final design. The focus of permaculture, therefore, is not on each separate element, but rather on the relationships created among elements by the way they are placed together; the whole becoming greater than the sum of its parts. Permaculture design therefore seeks to minimize waste, human labor, and energy input by building systems with maximal benefits between design elements to achieve a high level of synergy. Permaculture designs evolve over time by taking into account these relationships and elements and can become extremely complex systems that produce a high density of food and materials with minimal input.[13]

The design principles which are the conceptual foundation of permaculture were derived from the science of systems ecology and study of pre-industrial examples of sustainable land use. Permaculture draws from several disciplines including organic farming, agroforestry, integrated farming, sustainable development, and applied ecology.[14] Permaculture has been

applied most commonly to the design of housing and landscaping, integrating techniques such as agroforestry, natural building, and rainwater harvesting within the context of permaculture design principles and theory.

Theory

Twelve design principles

Twelve Permaculture design principles articulated by David Holmgren in his *Permaculture: Principles and Pathways Beyond Sustainability*:[15]

1. *Observe and interact*: By taking time to engage with nature we can design solutions that suit our particular situation.
2. *Catch and store energy*: By developing systems that collect resources at peak abundance, we can use them in times of need.
3. *Obtain a yield*: Ensure that you are getting truly useful rewards as part of the work that you are doing.
4. *Apply self-regulation and accept feedback*: We need to discourage inappropriate activity to ensure that systems can continue to function well.
5. *Use and value renewable resources and services*: Make the best use of nature's abundance to reduce our consumptive behavior and dependence on non-renewable resources.
6. *Produce no waste*: By valuing and making use of all the resources that are available to us, nothing goes to waste.
7. *Design from patterns to details*: By stepping back, we can observe patterns in nature and society. These can form the backbone of our designs, with the details filled in as we go.
8. *Integrate rather than segregate*: By putting the right things in the right place, relationships develop between those things and they work together to support each other.
9. *Use small and slow solutions*: Small and slow systems are easier to maintain than big ones, making better use of local resources and producing more sustainable outcomes.
10. *Use and value diversity*: Diversity reduces vulnerability to a variety of threats and takes advantage of the unique nature of the environment in which it resides.
11. *Use edges and value the marginal*: The interface between things is where the most interesting events take place. These are often the most valuable, diverse and productive elements in the system.
12. *Creatively use and respond to change*: We can have a positive impact on inevitable change by carefully observing, and then intervening at the right time.

Layers

Suburban permaculture garden in Sheffield, UK with different layers of vegetation

Layers are one of the tools used to design functional ecosystems that are both sustainable and of direct benefit to humans. A mature ecosystem has a huge number of relationships between its component parts: trees, understory, ground cover, soil, fungi, insects, and animals. Because plants grow to different heights, a diverse community of life is able to grow in a relatively small space, as each layer is stacked one on top of another. There are generally seven recognized layers in a food forest, although some practitioners also include fungi as an eighth layer.[16]

1. The canopy: the tallest trees in the system. Large trees dominate but typically do not saturate the area, i.e. there exist patches barren of trees.
2. Understory layer: trees that revel in the dappled light under the canopy.
3. Shrubs: a diverse layer of woody perennials of limited height. includes most berry bushes.
4. Herbaceous: Plants in this layer die back to the ground every winter (if winters are cold enough, that is). They do not produce woody stems as the Shrub layer does. Many culinary and medicinal herbs are in this layer. A large variety of beneficial plants fall into this layer. May be annuals, biennials or perennials
5. Soil surface/Groundcover: There is some overlap with the Herbaceous layer and the Groundcover layer; however plants in this layer grow much closer to the ground, grow densely to fill bare patches of soil, and often can tolerate some foot traffic. cover crops retain soil and lessen erosion, along with green manures that add nutrients and organic matter to the soil, especially nitrogen
6. Rhizosphere: Root layers within the soil. The major components of this layer are the soil and the organisms that live within it such as plant roots (including root crops such as potatoes and other edible tubers), fungi, insects, nematodes, worms, etc.
7. Vertical layer: climbers or vines, such as runner beans and lima beans (vine varieties)

[16][17]

Guilds

A guild is any group of species where each provides a unique set of diverse functions that work in conjunction, or harmony. Guilds are groups of plants, animals, insects, etc. that work well together. Some plants may be grown for food production, some have tap roots that draw nutrients up from deep in the soil, some are nitrogen-fixing legumes, some attract beneficial insects, and others repel harmful insects. When grouped together in a mutually beneficial arrangement, these plants form a guild.[18][19][20]

Edge effect

The edge effect in ecology is the effect of the juxtaposition or placing side by side of contrasting environments on an ecosystem. Permaculturists argue that, where vastly differing systems meet, there is an intense area of productivity and useful connections. An example of this is the coast; where the land and the sea meet there is a particularly rich area that meets a disproportionate percentage of human and animal needs. So this idea is played out in permacultural designs by using spirals in the herb garden or creating ponds that have wavy undulating shorelines rather than a simple circle or oval (thereby increasing the amount of edge for a given area).

Zones

Permaculture Zones 0-5.

Zones are a way of intelligently organizing design elements in a human environment on the basis of the frequency of human use and plant or animal needs. Frequently manipulated or harvested elements of the design are located close to the house in zones 1 and 2. Less frequently used or manipulated elements, and elements that benefit from isolation (such as wild species) are farther away. Zones are about positioning things appropriately. Zones are numbered from 0 to 5.[21]

Zone 0

> The house, or home center. Here permaculture principles would be applied in terms of aiming to reduce energy and water needs, harnessing natural resources such as sunlight, and generally creating a harmonious, sustainable environment in which to live and work. Zone 0 is an informal designation, which is not specifically defined in Bill Mollison's book.

Zone 1

> The zone nearest to the house, the location for those elements in the system that require frequent attention, or that need to be visited often, such as salad crops, herb plants, soft fruit like strawberries or raspberries, greenhouse and cold frames, propagation area, worm compost bin for kitchen waste, etc. Raised beds are often used in zone 1 in urban areas.

Zone 2

> This area is used for siting perennial plants that require less frequent maintenance, such as occasional weed control or pruning, including currant bushes and orchards, pumpkins, sweet potato, etc. This would also be a good place for beehives, larger scale composting bins, and so on.

Zone 3

> The area where main-crops are grown, both for domestic use and for trade purposes. After establishment, care and maintenance required are fairly minimal (provided mulches and similar things are used), such as watering or weed control maybe once a week.

Zone 4

> A semi-wild area. This zone is mainly used for forage and collecting wild food as well as production of timber for construction or firewood.

Zone 5

> A wilderness area. There is no human intervention in zone 5 apart from the observation of natural ecosystems and cycles. Through this zone we build up a natural reserve of bacteria, moulds and insects that can aid the zones above it.[22]

People and permaculture

Permaculture uses observation of nature to create regenerative systems, and the place where this has been most visible has been on the landscape. There has been a growing awareness though that firstly, there is the need to pay more attention to the peoplecare ethic, as it is often the dynamics of people that can interfere with projects, and secondly that the principles of permaculture can be used as effectively to create vibrant, healthy and productive people and communities as they have been in landscapes.

Domesticated animals

Domesticated animals are often incorporated into site design.[23]

Common practices

Agroforestry

Agroforestry is an integrated approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems.[24] In agroforestry systems, trees or shrubs are intentionally used within agricultural systems, or non-timber forest products are cultured in forest settings.[*citation needed*]

Forest gardening is a term permaculturalists use to describe systems designed to mimic natural forests. Forest gardens, like other permaculture designs, incorporate processes and relationships that the designers understand to be valuable in natural ecosystems. The terms forest garden and food forest are used interchangeably in the permaculture literature. Numerous permaculturists are proponents of forest gardens, such as Graham Bell, Patrick Whitefield, Dave Jacke, Eric Toensmeier and Geoff Lawton. Bell started building his forest garden in 1991 and wrote the book *The Permaculture Garden* in 1995, Whitefield wrote the book *How to Make a Forest Garden* in 2002, Jacke and Toensmeier co-authored the two volume book set *Edible Forest Gardening* in 2005, and Lawton presented the film *Establishing a Food Forest* in 2008.[13][25][26]

Tree Gardens, such as Kandyan tree gardens, in South and Southeast Asia, are often hundreds of years old. Whether they derived initially from experiences of cultivation and forestry, as is the case in agroforestry, or whether they derived from an understanding of forest ecosystems, as is the case for permaculture systems, is not self-evident. Many studies of these systems, especially those that predate the term permaculture, consider these systems to be forms of

agroforestry. Permaculturalists who include existing and ancient systems of polycropping with woody species as examples of food forests may obscure the distinction between permaculture and agroforestry.

Food forests and agroforestry are parallel approaches that sometimes lead to similar designs.

Hügelkultur

Hügelkultur is the practice of burying large volumes of wood to increase soil water retention. The porous structure of wood acts as a sponge when decomposing underground. During the rainy season, masses of buried wood can absorb enough water to sustain crops through the dry season.[27] This technique has been used by permaculturalists Sepp Holzer, Toby Hemenway, Paul Wheaton and Masanobu Fukuoka.[28][29]

Natural building

A natural building involves a range of building systems and materials that place major emphasis on sustainability. Ways of achieving sustainability through natural building focus on durability and the use of minimally processed, plentiful or renewable resources, as well as those that, while recycled or salvaged, produce healthy living environments and maintain indoor air quality.

The basis of natural building is the need to lessen the environmental impact of buildings and other supporting systems, without sacrificing comfort, health or aesthetics. To be more sustainable, natural building uses primarily abundantly available, renewable, reused or recycled materials. In addition to relying on natural building materials, the emphasis on the architectural design is heightened. The orientation of a building, the utilization of local climate and site conditions, the emphasis on natural ventilation through design, fundamentally lessen operational costs and positively impact the environment. Building compactly and minimizing the ecological footprint is common, as are on-site handling of energy acquisition, on-site water capture, alternate sewage treatment and water reuse.[*citation needed*]

Rainwater harvesting

Rainwater harvesting is the accumulating and storing of rainwater for reuse before it reaches the aquifer.[30] It has been used to provide drinking water, water for livestock, water for irrigation, as well as other typical uses. Rainwater collected from the roofs of houses and local institutions can make an important contribution to the availability of drinking water. It can supplement the subsoil water level and increase urban greenery. Water collected from the ground, sometimes from areas which are especially prepared for this purpose, is called stormwater harvesting.[*citation needed*]

Greywater is wastewater generated from domestic activities such as laundry, dishwashing, and bathing, which can be recycled on-site for uses such as landscape irrigation and constructed wetlands. Greywater is largely sterile, but not potable (drinkable). Greywater differs from water from the toilets which is designated sewage or blackwater, to indicate it contains human waste. Blackwater is septic or otherwise toxic and cannot be reused.

Sheet mulching

In agriculture and gardening, mulch is a protective cover placed over the soil. Any material or combination can be used as mulch, stones, leaves, cardboard, wood chips, gravel, etc., though in permaculture mulches of organic material are the most common because they perform more functions. These include: absorbing rainfall, reducing evaporation, providing nutrients, increasing organic matter in the soil, feeding and creating habitat for soil organisms, suppressing weed growth and seed germination, moderating diurnal temperature swings, protecting against frost, and reducing erosion. Sheet mulching is an agricultural no-dig gardening technique that attempts to mimic natural processes occurring within forests. Sheet mulching mimics the leaf cover that is found on forest floors. When deployed properly and in combination with other Permacultural principles, it can generate healthy, productive and low maintenance ecosystems.[31][32]

Sheet mulch serves as a "nutrient bank," storing the nutrients contained in organic matter and slowly making these nutrients available to plants as the organic matter slowly and naturally breaks down. It also improves the soil by attracting and feeding earthworms, slaters and many other soil micro-organisms, as well as adding humus. Earthworms "till" the soil, and their worm castings are among the best fertilizers and soil conditioners. Sheet mulching can be used to reduce or eliminate undesirable plants by starving them of light, and can be more advantageous than using herbicide or other methods of control.[*citation needed*]

Intensive rotational grazing

Grazing has long been blamed for much of the destruction we see in the environment. However, it has been shown that when grazing is modeled after nature, the opposite effect can be seen.[33][34] Also known as cell grazing, managed intensive rotational grazing (MIRG) is a system of grazing in which ruminant and non-ruminant herds and/or flocks are regularly and systematically moved to fresh pasture, range, or forest with the intent to maximize the quality and quantity of forage growth. This disturbance is then followed by a period of rest which allows new growth. MIRG can be used with cattle, sheep, goats, pigs, chickens, rabbits, geese, turkeys, ducks and other animals depending on the natural ecological community that is being mimicked. Sepp Holzer and Joel Salatin have shown how the disturbance caused by the animals can be the spark needed to start ecological succession or prepare ground for planting. Allan Savory's holistic management technique has been likened to "a permaculture approach to rangeland management".[35][36] One variation on MIRG that is gaining rapid popularity is called eco-grazing. Often used to either control invasives or re-establish native species, in eco-grazing the primary purpose of the animals is to benefit the environment and the animals can be, but are not necessarily, used for meat, milk or fiber.[37][38][39][40][41][42][43]

Keyline design

Keyline design is a technique for maximizing beneficial use of water resources of a piece of land developed in Australia by farmer and engineer P. A. Yeomans. The *Keyline* refers to a specific topographic feature linked to water flow which is used in designing the drainage system of the site.[44]

Fruit tree management

> The no-pruning option is usually ignored by fruit experts, though often practised by default in people's back gardens! But it has its advantages. Obviously it reduces work, and more surprisingly it can lead to higher overall yields.
>
> —Patrick Whitefield, *How to make a forest garden* p16

Masanobu Fukuoka, as part of early experiments on his family farm in Japan, experimented with no-pruning methods, noting that he ended up killing many fruit trees by simply letting them go, which made them become convoluted and tangled, and thus unhealthy.[45][46] Then he realised this is the difference between natural-form fruit trees and the process of change of tree form that results from abandoning previously-pruned unnatural fruit trees.[45][46] He concluded that the trees should be raised all their lives without pruning, so they form healthy and efficient branch patterns that follow their natural inclination. This is part of his implementation of the Tao-philosophy of Wú wéi translated in part as no-action (against nature), and he described it as no unnecessary pruning, nature farming or "do-nothing" farming, of fruit trees, distinct from non-intervention or literal no-pruning. He ultimately achieved yields comparable to or exceeding standard/intensive practices of using pruning and chemical fertilisation.[45][46][47]

Mollison and Holmgren

Bill Mollison in January 2008.

In the mid-1970s, Bill Mollison and David Holmgren started developing ideas about stable agricultural systems on the southern Australian island state of Tasmania. This was a result of the danger of the rapidly growing use of industrial-agricultural methods. In their view, highly dependent on non renewable resources, these methods were additionally poisoning land and water, reducing biodiversity, and removing billions of tons of topsoil from previously fertile landscapes. A design approach called *permaculture* was their response and was first made public with the publication of their book *Permaculture One* in 1978.[*citation needed*]

By the early 1980s, the concept had broadened from agricultural systems design towards sustainable human habitats. After *Permaculture One*, Mollison further refined and developed the ideas by designing hundreds of permaculture sites and writing more detailed books, notably *Permaculture: A Designers Manual*. Mollison lectured in over 80 countries and taught his two-week Permaculture Design Course (PDC) to many hundreds of students.[*citation needed*]

In 1991, a four-part television documentary by ABC productions called "The Global Gardener" showed permaculture applied to a range of worldwide situations, bringing the concept to a much broader public.[*citation needed*] In 2012, the UMass Permaculture Initiative won the White House "Champions of Change" sustainability contest, which declared that "they demonstrate how permaculture can feed a growing population in an environmentally sustainable and socially responsible manner".[48]

In 1997, Holmgren explained that the primary agenda of the permaculture movement is to assist people to become more self-reliant through the design and development of productive and sustainable gardens and farms.[14]

Trademark and copyright issues

There has been contention over who, if anyone, controls legal rights to the word *permaculture*: is it trademarked or copyrighted? and if so, who holds the legal rights to the use of the word? For a long time Bill Mollison claimed to have copyrighted the word, and his books said on the copyright page, "The contents of this book and the word PERMACULTURE are copyright." These statements were largely accepted at face-value within the permaculture community. However, copyright law does not protect names, ideas, concepts, systems, or methods of doing something; it only protects the expression or the description of an idea, not the idea itself. Eventually Mollison acknowledged that he was mistaken and that no copyright protection existed for the word *permaculture*.[49]

In 2000, Mollison's US based Permaculture Institute sought a service mark (a form of trademark) for the word, permaculture, when used in educational services such as conducting classes, seminars, or workshops.[50] The service mark would have allowed Mollison and his two Permaculture Institutes (one in the US and one in Australia) to set enforceable guidelines regarding how permaculture could be taught and who could teach it, particularly with relation to the PDC, despite the fact that he had instituted a system of certification of teachers to teach the PDC in 1993.This certification was granted to teachers like April Sampson-kelly and others in 1993. The service mark failed and was abandoned in 2001. Also in 2001 Mollison applied for trademarks in Australia for the terms "Permaculture Design Course"[51] and "Permaculture Design".[51] These applications were both withdrawn in 2003. In 2009 he sought a trademark for "Permaculture: A Designers' Manual"[51] and "Introduction to Permaculture",[51] the names of two of his books. These applications were withdrawn in 2011. There has never been a trademark for the word *permaculture* in Australia.[51]

Criticisms

General criticisms

In 2011, Owen Hablutzel argued that "permaculture has yet to gain a large amount of specific mainstream scientific acceptance," and that "the sensitiveness to being perceived and accepted on scientific terms is motivated in part by a desire for Permaculture to expand and become increasingly relevant." Bec-Hellouin permaculture farm engaged in a research program in partnership with INRA and AgroParisTech to collect scientific data.[52][53]

In his books *Sustainable Freshwater Aquaculture* and *Farming in Ponds and Dams*, Nick Romanowski expresses the view that the presentation of aquaculture in Bill Mollison's books

is unrealistic and misleading. However *Sustainable Freshwater Aquaculture* has likewise received criticism as being "too basic", "for primary school children" and "negative" in its approach.[54]

Linda Chalker-Scott alleges that Toby Hemenway's views regarding invasive species in the permaculture book *Gaia's Garden* are pseudoscience.[55][56]

Agroforestry

Greg Williams argues that forests cannot be more productive than farmland because the net productivity of forests decline as they mature due to ecological succession.[57] Proponents of permaculture respond that this is true only if one compares data from between woodland forest and climax vegetation, but not when comparing farmland vegetation with woodland forest.[58] For example, ecological succession generally results in a forest's productivity rising after its establishment only until it reaches the *woodland state* (67% tree cover), before declining until *full maturity*.[13]