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Design for Sustainability

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Module 3
Local food systems

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1. Introduction

In many ways, healthy local food is one of the best entry points into building sustainable communities, whether in an urban, peri-urban or rural area. Food invites us to think about our health, our local economy and our relationship with the land. As a basic need almost as important as clean drinking water, making sure we design resilient, productive, and regenerative food systems is the basis of a thriving community and region. This section is an introduction to ecological solutions to embed sustainability in farming practices and the important role of agriculture to mitigate the ravages of Climate Change in a regenerative manner. Given the proximity of agriculture and its interface with wilderness, it makes sense to explore solutions that are mutually beneficial and reinforcing to each other, such as, the care of land and forests and the bioremediation of waters.
In the content, it's introduced the context for this Module, whilst the subchapter 'Context' delves deeper into the context of the whole earth systems thinking related to agriculture and food in order to develop the rationale for embracing ecological solutions compared to other lesser sustainable solutions. Thereafter, the various whole systems regenerative thinking approaches that contribute towards sustainable agriculture are outlined before unpacking a few of the more relevant approaches. This follows with some applications and integration of sustainable design solutions. Sustainable Food Systems are then explored to show the interaction between farmers and consumers. A design process with case study examples is provided before the concluding remarks.

Context

The emergence of formal cultivation of land, and hence the term agriculture, was heralded as one of civilisation's greatest inventions. And indeed, the yield of surplus production was a huge asset that led to the ensuing development of early settlements into market towns and eventually into cities. However, the growth of these early settlements was generally in accordance with the surrounding available food producing land plus food derived from conquests. The inability to sustain these food supplies often led to the downfall and shrinkage of these early settlements. In modern times, the lands surrounding urban expansion are often under speculation and lost to market gardening. The survival of these cities is only possible through the global economy which moves mountains of food from far off farms to urban areas. Furthermore, the cost of food transportation is a major contributor to food miles and GHG emissions, whilst the development of transport networks and the maintenance thereof is an increasing burden upon the taxpayer.

The dominant agricultural methodology from its inception to the current has been the initial clearance of virgin land and subsequent tillage of such land by breaking open the soil to facilitate the planting of seeds. Initially, the tillage was done with handheld and animal drawn implements, which is still undertaken to this day in many third world countries. The onset of the Industrial Revolution saw human and animal power being replaced with steam and later fossil fuels at an industrial scale.

However, put simply, whilst this tillage method of agriculture facilitated civilisation, in hindsight, it has come at a significant environmental cost. More specifically, the organic carbon or humus that was originally in the undisturbed soil was exposed to the elements as tillage broke open the soil, thus allowing the drying out and erosion of the humus, which eventually evaporates into CO_2 and is a major contributor to the global CO_2 emissions. Furthermore, since the end of the First World War when large stockpiles of chemical weapons were left over, this surplus was soon reconstituted into the initial chemical fertilizers, notably, the primary macronutrients comprising Nitrogen (N), Phosphorus (P) and Potassium (K), also known as NPK, to feed the soils whose constant tillage had depleted the humus. The initial success of these chemical fertilizers was apparently quite significant, but perhaps because it was applied to humus depleted soils, thereby showing improved production yields. However, the folly of the extensive use of these chemical fertilizers and the ensuing use of pesticides and herbicides, has left a trail of destruction in the once fertile soils, so much so, that the health and wellbeing of nature and human civilisation is compromised. It suffices to state that without humus, the soil has no life, thereby rendering the soil infertile. Sadly, farmers are continually depleting vast tracts of agricultural land, and in desperation, are applying an ever-increasing cocktail of genetically modified seeds, chemical fertilizers, pesticides and herbicides, in an attempt to sustain yields, but with limited success. And in so doing, these farmers are further adding to the global CO_2 emissions.

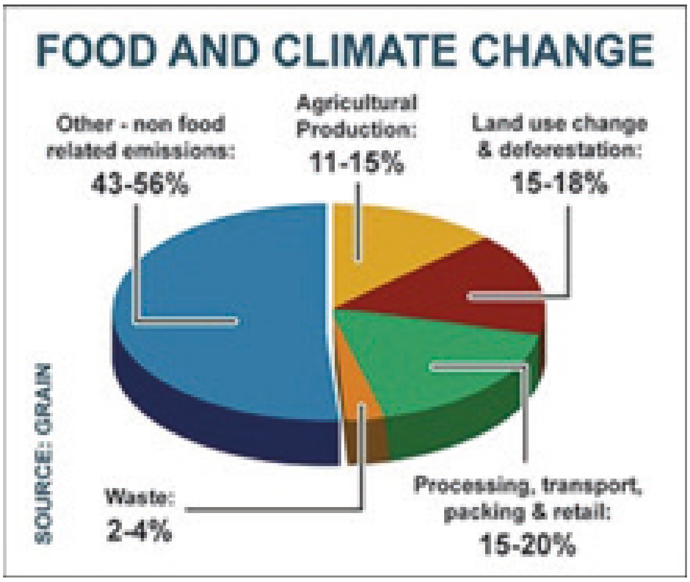


Figure 1.2: Agricultural contribution to CO2

2.

The Rationale for Regenerative Agriculture

2.1. Biodiversity and the Soil Microbiome

The IPBES Global Assessment Report published in May 2019 for the UN Convention on Biological Diversity puts habitat loss as the number one direct driver of the loss of biodiversity and species extinctions with agriculture and urbanisation mentioned as the primary drivers. The report specifically states that climate change is not a direct driver of habitat loss but exacerbates existing drivers. To recap, in Module 2, we also looked at the disruption of the hydrological cycle and saw that ecosystems were dehydrated by loss of vegetation and urbanisation leading to desertification and collapse. In this module, we will look at the many ways that we can regenerate ecosystems and restore the carbon and hydrological cycles through a transition to agro-ecological practices appropriate to our own bioregion. It comes at a moment in time when the IPCC has also published the Climate Change and Land report (August 2019) with suggestions for using reforestation and regenerative agriculture as Negative Emissions Technologies to draw down carbon dioxide from the atmosphere as part of a Net Zero Emissions strategy to tackle climate change. We will also look at the potential for carbon sequestration among the various agricultural methods proposed.

The 'conventional' agricultural practices that were implemented during the so-called Green Revolution in the 1960s have produced increased yields of grains, but at a terrible cost to the land and to farmers. In the global North, governmental and EU systems of subsidies for farmers have obliged them to remove hedgerows, drain wetlands and log woodlands to qualify for payments and the dominance of supermarket chains and food processing transnationals in the retail sector have forced down the price they are paid for their produce. Farmers are also squeezed through debts to banks and agri-businesses: modern farm equipment comes with a price and the cost of seed, artificial fertilisers and chemicals from the big corporations keep farmers on the treadmill. As small farmers go out of business or retire, their land is taken over by corporate agribusinesses, and those farmers that remain are locked into the subsidy system, with degraded land and massive loans that render change almost impossible. This is why they need help and support to make the transition from consumers like ourselves and from our governments and institutions.

'Conventional' agriculture, also referred to as 'specialised industrial agriculture' (SIA) requires massive inputs of chemicals in the form of fertilisers, pesticides, herbicides and fungicides which has a profound effect on the environment. Recent tests carried out in Germany show that glyphosate, the most commonly used herbicide, can be found in rainwater, tap water, urban dust and in human urine. Runoff from compacted fields also carries nitrogen and phosphates poisoning rivers and lakes. The nitrogen feeds algal blooms which cut off oxygen from other species causing 'dead zones' in the oceans where marine life cannot survive. 'Conventional' agriculture removes habitat for wildlife. When this happens, we lose the ecosystems functions that maintain a healthy environment and functional cycles of the biosphere, as illustrated in **Figure 2.1**.

Global trade in foodstuffs is equally a driver of degradation and carbon emissions. It is largely unnecessary and is a particular driver of socio-economic and environmental injustice in the global South. The UN Rapporteur on the Right to Food, Professor Olivier de Schutter, has called repeatedly for an end to the global trade in food and a transition to food sovereignty facilitated by small-scale agro-ecology. Naturally, a transition to regenerative agriculture and sustainable food production and consumption is essential to achieving the Sustainable Development Goals. Eliminating poverty, hunger and inequality are evidently achievable through a transition to local, regenerative agricultural practices, but likewise education and urbanisation can be positively impacted by a transition to locally grown food, and the environmental goals cannot be achieved at all without a transition. Agriculture is the key to a regenerative future.

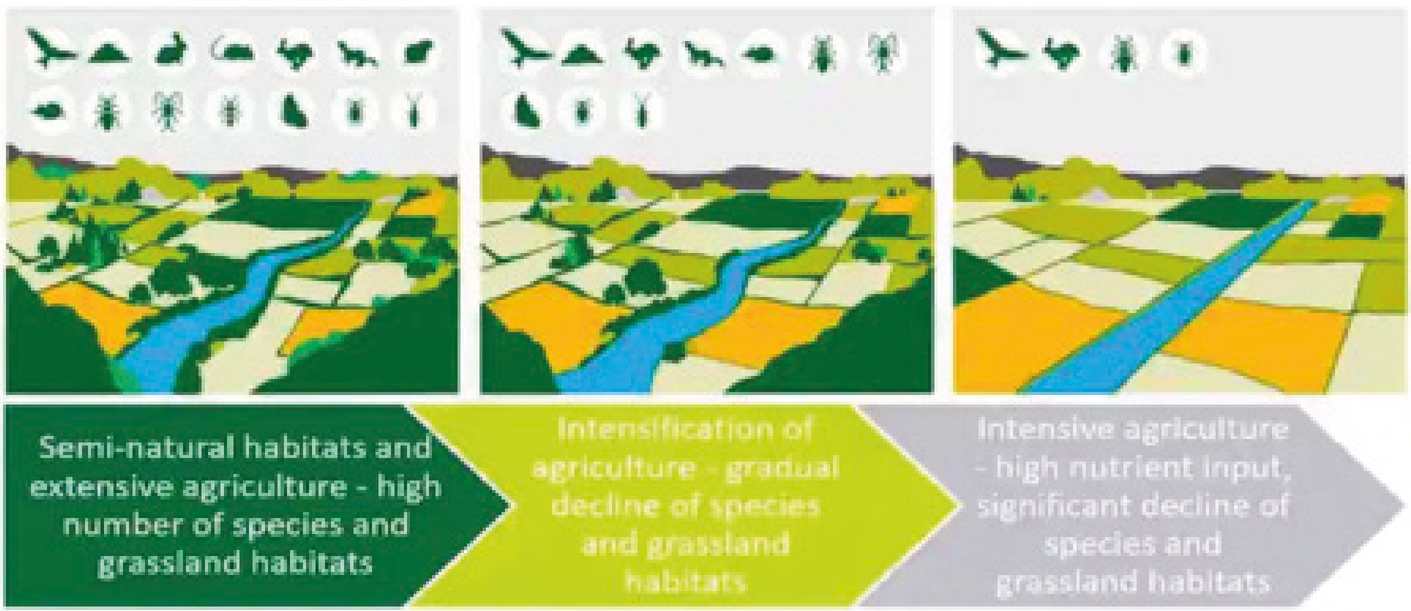


Figure 1: Decline in farmland biodiversity due to intensification of land use. Source

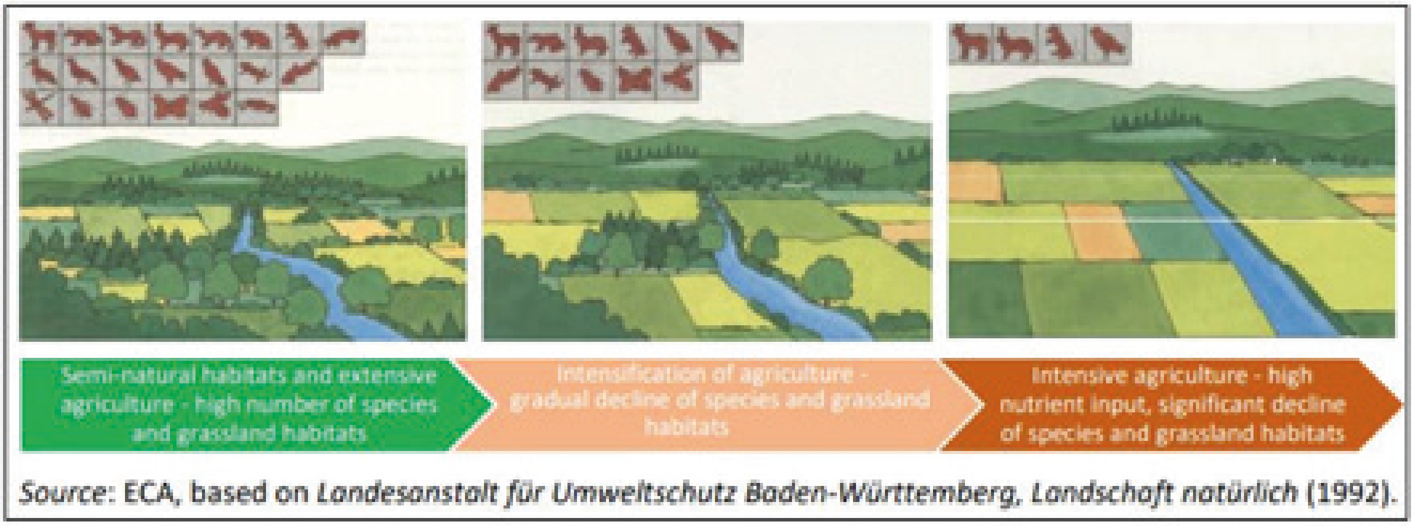


Figure 2.1: Changes of biodiversity on farmland due to intensification of farmland use. [*Source*]

Agro-ecology is used as an umbrella term to describe a range of practices or it is the term that designates a particular practice in some countries, particularly in the global south. It implies growing food as a form of edible ecosystem in which farmers mimic nature for diversity, fertility, pollination and (biological or integrated) pest control. As natural ecosystems are polycultures consisting mostly of perennials with high levels of biodiversity below and above ground and a ‘sponge’ of soil organic carbon that maintains the water cycle, it makes sense that the proposed methods include these features. We find agro-forestry and silvopasture combining productive trees with crops and animals are the most productive in some bioregions where open-canopy woodlands with meadows are the norm, and they also sequester high levels of CO_2. No-till polyculture cropping in rotation with animals is also being researched extensively with groundcover crops that build soil carbon and maintain the soil microbiome. When savannah or prairie is the predominant biome, stamped into the landscape by massive herds of bison or other ungulates (hooved animals), grazing cattle can be used (see mob grazing and holistic planned management) to restore and rehydrate grasslands. Ungulates can also be used to ‘wild’ degraded arable land restoring it to biodiverse ecosystems.

Permaculture, which perfectly matches the biome to the methods through detailed and conscious design, straddles all of these and is admirably suited to regeneration of entire watersheds. Urban agriculture is already showing great promise as means to provide inhabitants with food security while enhancing urban ecology, greening and cooling cityscapes.

No monoculture of annual crops or animal husbandry that relies on inputs (chemical or organic) from outside the ecosystem will ever be sustainable; it is more like mining the soil than farming.

2.2. Biodiversity and the Soil Microbiome

Life on Earth is sustained by a very thin crust of living soil. The fundamental basis of all regenerative forms of agriculture is healthy living soils. Extensive interdisciplinary research blending botany, biology and ecology with microbiology has shown that the symbiotic relationship between plants and microbial life in the soil is crucial to the health of all plant life and the nutritional value of the food we eat. Moreover, healthy living soil is the key to a healthy biosphere, and it forms the basis for all those interconnections that keep the cycles functioning. Healthy living soil contains an abundance of mycorrhizal fungi and bacteria (see Figure 2.2a). The Human Microbiome Project has revealed that 90% of the genetic material on and in our bodies is microbial. We are an ecosystem. Our gut microbiome weights over 2kg and it is responsible for building our immune system, regulating our metabolism and even our moods by sending neurotransmitters through the vagus nerve to affect our brain chemistry. In our digestive tract, microbes digest fibre, manufacture enzymes and vitamins, crowd out pathogenic bacteria, and clean and repair the gut wall. Without them we would die and so would they. Keeping us healthy and alive is in their interest too. Our gut microbiome is the primary interface with the microbial world outside via our food. There are direct interactions between our gut microbiome and the soil microbiome.

The soil microbiome relies on plants to provide carbohydrates for its energy source. Plants create sugars through photosynthesis and some of these, up to 70% in some cases, is exuded into the soil through roots. There it feeds the mycorrhizal fungi and bacteria that in return pass nutrients and water to the plants. In forests, it has been shown, that mycorrhizal fungi carry chemical messages (pheromones) and sugars between trees forming a symbiotic network of communications and nurture. They also produce chemicals that are antiviral and antimicrobial to treat wounds and diseases and can attract and repel other species as necessary. When there are significant numbers of microbial communities present, they take part in what microbiologists call 'quorum sensing'; they can 'decide' to enhance the nutritional content of plants and can even switch plant genes on and off. Naturally, as

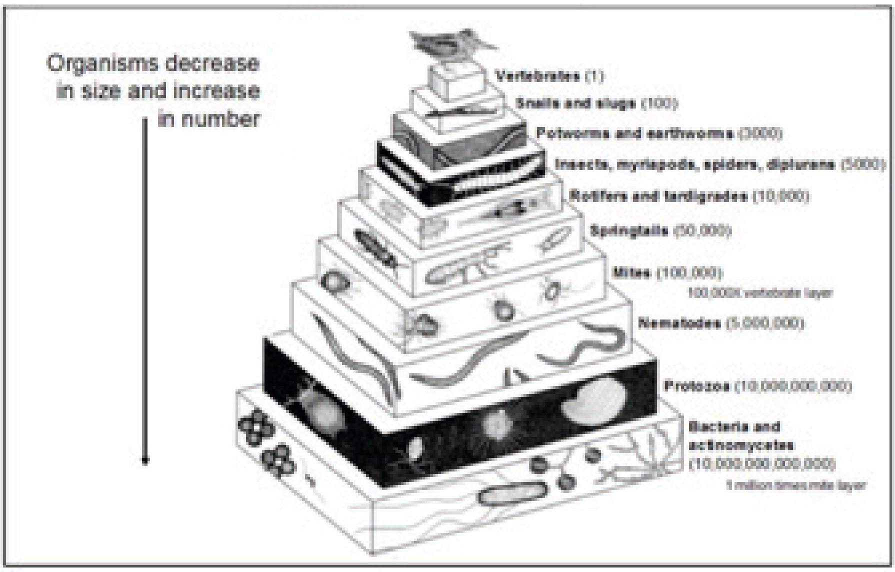
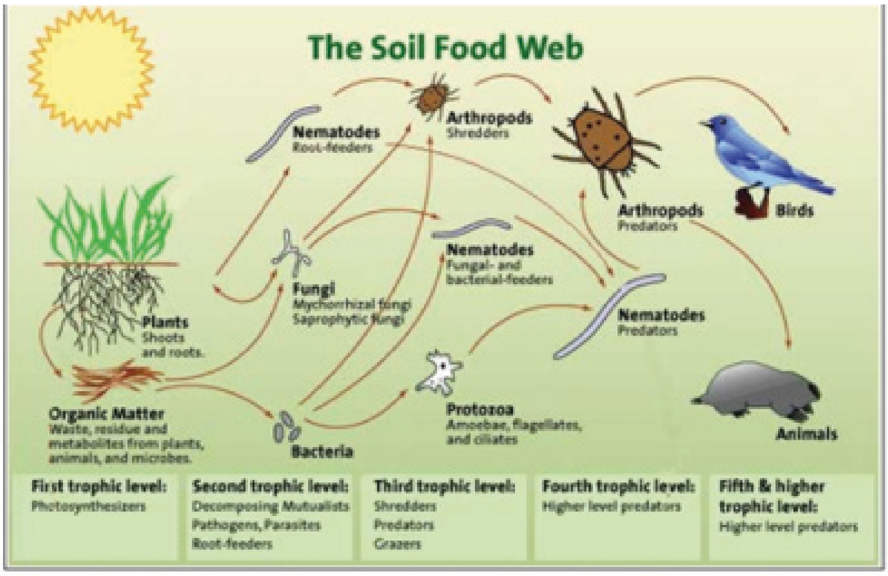


***Figure 2.2a:** The biology pyramid in one m2.(**Source:** Soil)*



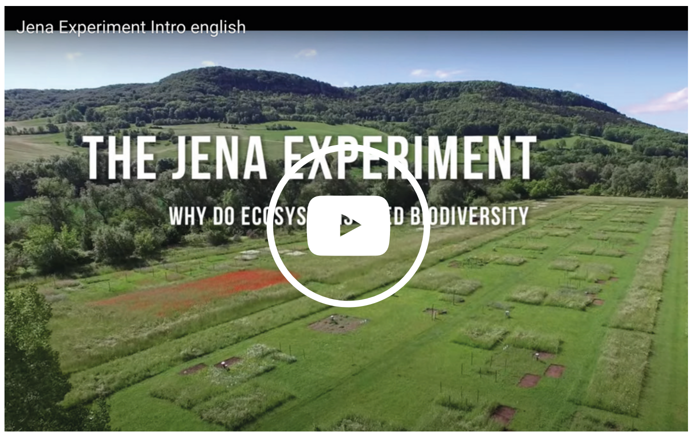
*The soil food web, shown in **Figure 2.2b**, breaks down organic matter, increasing soil organic carbon and making nutrients available for plants.*

the plants are feeding the microbes, it is in their interests to keep those plants healthy and functioning. A diverse polyculture of plants above ground ensures a large number of microbial communities below ground.

The potential for producing large quantities of healthy food for human health and well-being while regenerating ecosystems is vast. But our present agricultural systems are doing the opposite. Artificial fertilisers, agricultural chemicals and continuous tilling and digging for annual crops kills the soil microbiome. Because we mistakenly believe we have to add nutrients to the soil, we are also killing the microbiome. Soil does not need amendments if we nurture the microbiome. Microbes can produce enough reactive nitrogen for uptake by plant roots, others release minerals from parent material and make them available, even passing them from nutrient rich areas to nutrient poor areas. And it is microbial life that creates soil itself (as opposed to 'dirt') using the sugars exuded from roots, breaking down dead matter, creating substances such as glomalin that create that rich, friable, crumbling texture that is the organic carbon sequestered in soil.

Animals also build soil organic carbon by consuming fibres such as cellulose in grass and their dung is food for invertebrates and soil microbes. Cattle dung can support up to 250 species of invertebrates at one or another point in their life cycles, thus adding considerably to maintaining biodiverse ecosystems as well as soil organic carbon and microbial communities.

While the food chain above ground is a 'grazing food chain' in which energy (sugars) provided by plants through photosynthesis is passed upwards from the primary consumers (herbivores), through carnivores and up to the top predators (including humans), the food chain below ground is the 'detrital food chain' which breaks down waste and dead matter into the nutrients that again can feed the plants. This is the nutrient cycle, one of the biosphere's functional cycles, and it is fundamental to all life on Earth. We take part in both these food chains and the nutrient cycle which is driven by the symbiotic relationships between plants and soil life.



Watch this short video about the Jena Experiment at the Frederich Schiller University in Germany were field trials over a ten year period showed the conditions necessary for sustaining biodiversity.

2.3. The Soil Microbiome and the Nutrient Cycles

As we have seen, microbial life has existed on this planet for around 3.8 billion years and has been the driving force of evolution, changing the gaseous composition of the atmosphere, laying down minerals as sedimentary rocks and creating the soil that is the basis for all life as we know it. Humans have known about microbial life for hundreds of years, but recent developments in research technology (e.g. 'batch sequencing) are revealing the full extent of microbial involvement in maintaining life on the Earth and their crucial role in the functional cycles of the biosphere. In Module 1 we looked at the overall picture; in Module 2, we looked at aerobic and anaerobic microbes based on their relationship to oxygen; but microbiologists are now finding remarkable microbes that rely on other chemical processes for respiration and energy and can even switch nimbly from one process to another according to the elements available.

The greatest (theoretical) grandmother of all life on Earth, fondly called LUCA (Last Universal Common Ancestor) was most likely such a creature with remarkable flexibility for survival, nimbly switching between processes for extracting energy from a wide range of organic and inorganic elements, which is no doubt why all life as we know it has descended from her with such a broad range of specialisations and commonalities. Paradoxically, it was life itself that saved planet Earth from the sterile fate of our neighbours Mars and Venus and it is life itself that will make the most crucial contribution to resolving the current biosphere crisis: biodiversity loss, desertification and climate change.

Thanks to our microbial cousins, mineral nutrients attached to electrically-charged particles in the soil (called cations) can be liberated and made available for uptake by plant root systems. Plants use these nutrients to create the enzymes, vitamins, essential oils and proteins they need. They also use them to create complex compounds we experience as taste and aroma. The compounds in plants like onions and garlic are obvious, but the expertise in organic chemistry exhibited by plants is astonishing. The odour of Elderflower blossoms, for example, requires a combination of nine chemical compounds, all of which have been manufactured by the tree from the basic nutrients it acquired from the soil, and brought together in exactly the right combination to produce the smell. Plants have a remarkable agency we have poorly understood; they are the absolute masters of organic chemistry on this planet, but it's also clear that soil is the basis for all health as the compounds in plants are our source of essential minerals. Food is medicine only if we have a healthy soil microbiome, the soil bacteria and mycorrhizal fungi that provide the mineral nutrients to plants. Everything is connected.

At present, our industrial agriculture is destroying the bacteria and mycorrhizal fungal networks and impacting on our health. We have a recipe for a catastrophe and reducing pesticides alone is not enough to regenerate soil; we have to ensure that our farming methods transition from inorganic nitrogen fertilisers to agro-ecological methods that restore the symbiotic relationship to produce the organic nitrogen plants need to build proteins as well as the other nutrients.

More information on pedogenesis (soil creation), plant health and its influence on our own health can be found in this video by Dr Walter Jehne, soil microbiologist and campaigner for ecosystem restoration as a solution to the biosphere crisis. This is not an obligatory part of the module material, but is excellent additional, in-depth information for participants with a particular interest in agriculture.

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2.4. The Soil Microbiome and the Nutrient Cycles

The monoculture landscapes of industrial agriculture has resulted in a significant loss of seed varieties. Research done in 1983 by the Rural Advancement Foundation International, (RAFI), highlighted this loss of seed diversity by comparing listings of seed varieties sold by commercial seed companies in 1903 with those in the US National Seed Storage Laboratory in 1983. The survey of 66 crops, found that some 93% of the varieties had gone extinct. See Figure 2.4 for some of the seed loss comparisons.

The loss of seed varieties has been a direct result of large transnational corporations that have acquired many small seed companies and now control a majority percentage of seeds for the global food economy. Moreover, many of these seeds are now genetically modified (GMOs), which has further tampered with Nature's realm and also made many farmers dependent on support from these transnational agro-corporations.

The control of seed varieties by private corporations is a global challenge which affects food sovereignty. Nevertheless, the adoption of sustainable agricultural systems promotes the establishment of biodiversity with enhanced seed varieties, thus resulting in greater food sovereignty resilience. This also creates a huge opportunity for heirloom seed companies to flourish and be the spark that regenerates agriculture.

In protest against the transnational corporation's grip on seed sovereignty, a leading environmental activist, Vandana Shiva, co-founded the Navdanya NGO in India to create awareness about seeds, healthy food and sustainable forms of agriculture. Navdanya has since grown into a national movement in India and also a Global Seed Freedom Movement. In a recent article, Vandana Shiva stated that, "In an era of climate change, rejuvenating and regenerating the soil through ecological processes has become a survival imperative for the human species", whilst in this short video (3 mins), she talks about the Seed Freedom Movement.

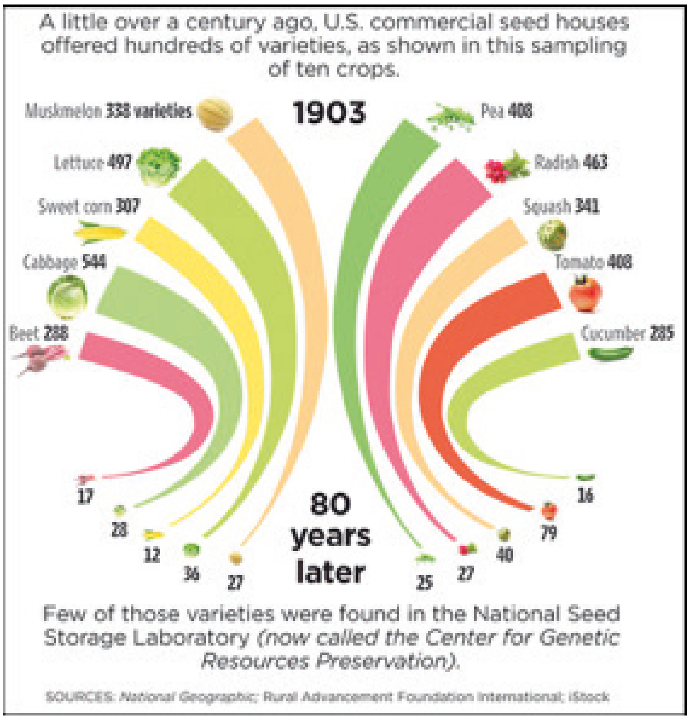

Figure 2.4: Our dwindling seed variety

2.5. The Industrialisation of Agriculture

The production of food by human societies has gone through many changes over the centuries, from hunting and gathering through locally based systems of agriculture and finally to industrial agriculture. All these stages can still be seen on Earth today but as a generalisation it can be said that the countries that industrialised in the nineteenth century now have a predominantly industrial style of agriculture, whereas the so called "two-thirds world" typically has areas of industrial agriculture, often foreign owned, in a matrix of locally based human scale agriculture. We can characterise the differences between these systems by looking at the various elements involved in the process of food production: land, energy, inputs, people, trade and food itself.

Industrial agriculture delivers larger yields in terms of crops and animal products than under any previous farming system. However, this is coming at a heavy price. Chemical fertilisers are reducing the fertility of the soil and polluting rivers, lakes and the ocean through run-off. There are significant levels of chemical poisoning among farm workers, especially in parts of the world where there are insufficient standards and safeguards. Industrial agriculture uses far more water than traditional farming methods. This both depletes groundwater and aquifer reserves and deprives small-scale farmers, local people and other species access to water.

Industrial agriculture also poses a serious threat to biodiversity. This is both because the supermarkets that now deliver food to most people in the industrialised countries of the North have an interest in selling a relatively small range of cultivars of each foodstuff (cereals, beans, vegetables, etc.) in large quantities and because monoculture plantations are poor habitats for the endemic plant and animal life that thrives in small-scale, diverse farms. Genetically modified (GM) varieties of crops now present in many countries also bring with it significant dangers to genetic stock of traditional varieties as well as currently largely unquantified dangers to

Local Human Scale Agriculture		Industrial Agriculture
Land	Sacred space	Tradable commodity
	Rights of use	Ownership
Energy – Net energy production		Net energy consumption
Inputs	Local inputs (e.g. seeds)	Standard inputs
	Mechanical weed control	Chemical weed control
People	Land user to land owner/occupier	Corporate owner
	Calling of the land	Businessman
	Eating local food	Passive consumer
Trade	Local self-sufficiency with	Food as commodity
	surplus traded	internationally traded
Food – Source of health, celebration and connection		Convenience food or even food addictions

Table 2.5: Comparison of Local Human Scale Agriculture versus Industrial Agriculture (Source: GRAIN)

***Read more here:** https://www.eitfood.eu/blog/post/can--regenerative-agriculture-replace-conventional-farming* human health. You can find more information about this issue on the Institute for Science in Society website.

In addition, industrial agriculture replaces people with machines, requiring less people on the land, which in turn effects rural communities. Government subsidies are available for farmers in the USA and the European Union, enabling their farmers to out-compete farmers in poorer countries (we will return to this in the Economic Dimension). This has serious consequences for the rural economies and societies in the two-thirds world. Large corporations control the distribution of seeds and other inputs as well as the growing of many crops. One significant consequence of this is that where previously people had an intimate and meaningful connection with the food they ate, today for many it has become a commodity like any other.

Finally, and perhaps of most urgent concern, industrial agriculture is heavily dependent on easy access to cheap fossil fuels, which is unsustainable. The high level of efficiency claimed for industrial agriculture does not take into account whole systems costs. More energy is required to produce food by industrial methods compared with organic methods. In Britain, organic agriculture has about 50% of the carbon footprint of its conventional equivalent.

Meanwhile, in contrast to industrial agriculture, there are many movements which have stood against this system and attempted to justify the environmental and socio-economic benefits of sustainable systems of agriculture. For example, GRAIN is an international non-governmental organisation which promotes the sustainable management and use of agricultural biodiversity based on people's control over genetic resources and local knowledge (**see Table 2.5**). Another example is, La via Campensina is an international movement of peasants, small- and medium-sized producers, landless, rural women, indigenous people, rural youth and agricultural workers.

2.6. The potential of carbon sequestration to mitigate Climate Change

This section has thus far elaborated on the importance of soils rich with organic carbon, or humus, to support a greater biodiversity and life on earth in general. Yet, despite this knowledge, humanity still pursues industrial agricultural practices which destroys life in the soil and all supporting ecosystems, besides releasing huge amounts of GHGs into the atmosphere. Nevertheless, there is a growing awareness of these dangers, together with sustainable solutions to transform agriculture to more sustainable practices. In particular, the astounding ability of regenerative agricultural practices to restore humus rich soils that can sequester carbon from the atmosphere.

In April 2014, the Rodale Institute published a white paper on Regenerative Organic Agriculture and Climate Change that outlines how agricultural techniques available today could sequester sufficient amounts of atmospheric carbon to slow down climate change and reduce greenhouse gas concentrations in the long term by fixing carbon in agricultural soil. Regenerative agricultural practices can help to build fertile soils, to maintain and often increase agricultural yields, and to support ecological abundance by nurturing healthy ecosystem functioning. The report states:

"Simply put, recent data from farming systems and pasture trials around the globe show that we could sequester more than 100% of current annual CO_2 emissions with a switch to widely available and inexpensive organic management practices, which we term regenerative organic agriculture. These practises work to maximize carbon fixation while minimizing the loss of carbon once returned to the soil, reversing the greenhouse effect".

Rodale Institute, *(2014).*

Robert Rodale coined the term 'regenerative organic agriculture' to indicate that these practices are more than simply 'sustainable', taking advantage of the natural tendencies of ecosystems to regenerate when disturbed. Regenerative organic agriculture is "a holistic systems approach to agriculture that encourages continual on-farm innovation for environmental, social, economic and spiritual well being". In general, "regenerative organic agriculture is marked by tendencies towards closed nutrient loops, greater diversity in the biological community, fewer annuals and more perennials, and greater reliance on internal rather than external resources", (Rodale Institute, 2014).

The World Bank has released a detailed report on Carbon Sequestration in Agricultural Soils which reviews the different 'abatement rates' (measured in tonnes of carbon dioxide equivalent sequestered per hectare per year) of different land management practices and how effective they are in different regions of the world. The report highlights that "in addition to storing soil carbon, sustainable land management technologies can be beneficial to farmers because they can increase yields and reduce production cost".

Change in the capacity of soil to store water (litres/ha) with changes in levels of soil organic carbon (OC) or humus to 30cm of soil depth. Bulk Density 1.2g/cm3				
Change in OC Level	Change in OC (kg/m2)	Extra water (litres/m2)	Extra water (litres/ha)	CO_2 Seq. (t/ha)
1%	3.6	14.4	144,000	132
2%	7.2	28.8	288,000	264
3%	10.8	43.2	432,000	396
4%	14.4	57.6	576,000	528
Source: Dr. Christine Jones (www.amazingcarbon.com)				

Table 2.6: Quantifying the benefits of humus in the soil

At this point, it is worth noting the typical composition of undisturbed soil in nature, which is approximately 46% grit, 25% water, 25% air and 4% humus (organic living matter). With convention-type agriculture that tills and compacts the soil, the air and water is squeezed out whilst the humus is destroyed through the application of chemical fertilizers, pesticides, herbicides, fungicides, etc., thereby resulting in a hard compacted and lifeless soil. Limited till methods rip the soil thereby allowing air and water penetration for plant roots to take up essential minerals. In time, as this process is repeated with an appropriate regime of crop rotations and controlled mob grazing, the humus is restored back to its original undisturbed state. The humus in the soil is effectively the glue which binds the grit, water and air. Therefore, as the humus levels increase, so does the ability of the soil to retain moisture and sequester carbon. Dr. Christine Jones (www.amazingcarbon.com) has documented this research, as reflected in **Table 2.6**, which shows how an increase in one percent humus (or Organic Carbon) effectively doubles the moisture retention and carbon sequestration of the soil.

Since conventional agriculture has rendered the average farm soil to less than 0,5%, there is an incredible potential to simply restore soils through Regenerative Agriculture so that moisture can be retained, plant vitality can be increased, but even better, carbon can be sequestered.

Since conventional agriculture has rendered the average farm soil to less than 0,5%, there is an incredible potential to simply restore soils through Regenerative Agriculture so that moisture can be retained, plant vitality can be increased, but even better, carbon can be sequestered.

The Regrarians have quoted PA Yeomans as saying that if all the arable land on earth manages to increase its humus content by just 1,6% in the top 30cm of soil, it will be sufficient to revert to 299 ppm of CO2 in the atmosphere from the current 413 ppm within a few years.

It can therefore be argued that farmers of the world have the potential to almost single-handedly sequester the earth's entire CO2 emissions by reverting to an acceptable CO2 level that ought to curb runaway Climate Change. If sufficient moral emphasis is placed on all stakeholders - government, corporations and the private sector – to invest in the global carbon markets to buy back CO2 emissions, is this not then the investment game changer to drive Regenerative Agriculture?

Dr. Elaine Ingham has made similar estimates in the video titled, "Soil Carbon Sequestration and the Soil Food Web", which is encapsulated in the statement, "Climate Change poses an existential threat to humanity. Soil Carbon Sequestration is widely being recognized as a part of the solution to this problem". Putting the soil carbon back into the soil also supports greater biodiversity and species regeneration.

3. Whole Systems Approach

3.1. Systems of Sustainable Agriculture

Having provided the context and rationale for a regenerative form of agriculture, this section introduces (in no specific ranking order) the mainstream whole systems approaches to sustainable agriculture in order to appreciate the valuable contributions to this sector, some of which are subsequently expanded with examples.

- **Permaculture:** the application of design principles for a permanent (sustainable) form of agriculture, hence the word "perma-culture", which is built upon a sound ethical foundation that considers the earth, people and distribution of resources.

- **Organic Farming:** an agricultural approach that does not do harm to an environment by avoiding chemical fertilizers, pesticides, herbicides, fungicides in the manner that crops are cultivated, processed and packaged for consumers.

- **Natural Farming:** also known as "do nothing farming" is a closed loop system with minimal human input and that mimics nature with no fertilizers, no pesticides, no tillage and no weeding.

- **Biodynamic:** appreciates the farm terrain as a living membrane which breathes with the seasons, and which functioning can be enhanced by homeopathic-type dosages of unique plant preparations applied to the landscape and in compost making.

- **Holistic Management:** looks at the farm enterprise as a whole system and plans the integration of cultivation and grazing by mimicking how nature behaves, in particular, the herd and predator relationship.

- **Agro-ecology:** a term which embraces several approaches to sustainable agriculture which mimics the ecological processes in nature for application to agricultural production processes.

- **Yeomans Scale of Permanence or the Keyline System:** this approach outlines the sequence of design leading to a regenerative farm design.

- **Regenerative Agriculture:** this combines Permaculture design principles with Holistic Management to enhance a whole systems thinking approach for taking on a design process led by Yeomans Scale of Permanence.

- **Syntropic Agriculture:** is an approach which focuses on establishing agroforestry in a rapid process that mimics nature's growth by selecting specific mutually supporting plant guilds and through extensive initial pruning.

- **Limited Till Farming:** an approach that avoids the turning of soil such as tilling in order to minimize soil compaction, thereby enhancing the aeration, moisture penetration and humus building in soils.

- **Conservation Agriculture:** a form of agriculture that minimizes the disturbance of soils and uses some of nature's elements to embed sustainability.

- **Agroforestry:** a land use management system in which trees or shrubs are grown around or among crops or pastureland in order to create more diverse, productive, ecologically sound and sustainable land-use systems.

- **Carbon Farming:** a regenerative approach to agriculture that reduces GHG emissions or captures and holds carbon in vegetation and soils through the design and management of landscape-based rainwater harvesting, plant guilds and livestock.

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The above list is not exhaustive, but it does highlight the many initiatives to have evolved as sustainable solutions against the challenges of industrial systems of agriculture. It is beyond the scope of this Module to explore all of the above, but some of the most noteworthy approaches to sustainable agriculture are explored in more detail under this section and in later sections by way of examples and case studies.

3.2 Permaculture design system

Permaculture history and context

The term Permaculture was created by Bill Mollison and David Holmgren in 1978 in Australia, to describe a design-based approach to creating a permanent agriculture as a system that can support cultures with permanence. In its widest sense it is an approach to creating sustainable and regenerative socio-ecological systems. As such Permaculture can be understood as conscious design of a sustainable future, based on co-operation with Nature and caring for the Earth and her peoples.
scenario of famines, disease and wars over resources. Mollison and Holmgren were among the few who actually sat back and calmly asked what a planned and measured 'energy descent', one that embraced a whole-systems approach to resources, would look like. The result of their collaboration was Holmgren's dissertation, published as Permaculture One in 1978.

Permaculture draws together knowledge and skills from many ecological disciplines - old and new - to meet our basic needs for food, shelter, holistic social structures and sustainable economies. Permaculture is a design system for creating sustainable human environments. The word itself is a contraction not only of permanent agriculture but also of permanent culture, as cultures cannot survive for long without a sustainable agricultural base and land use ethic. On one level, Permaculture deals with plants, animals, buildings, and infrastructures, as well as water, energy & communications. However, Permaculture is not about these elements themselves, but rather about the relationships we can create between them by the way we place them in the landscape.

The aim is to create systems that are ecologically-sound and economically viable, which provide for their own needs, do not exploit or pollute, and therefore are sustainable in the long term. Permaculture uses the inherent qualities of plants and animals, combined with the natural characteristics of landscapes and structures, to produce life-supporting systems for city and country, using the smallest practical land area.

Permaculture is based on the observation of natural systems, the wisdom contained in traditional farming systems, and modern scientific and technological knowledge. The old motto "Natura mater et magistra" - Nature is both mother and teacher – applies yet again. Based on ecological models, Permaculture creates a cultivated ecology, which is designed to produce more human and animal food than is generally found in Nature.

When the needs of a system are not predominantly met from within the system, we pay the price in energy consumption and pollution. A fundamental change is necessary. To live a good and healthy life human beings need more than communication technology devices and virtual reality. Our very being and sanity depends on frequent contact with sun, wind, people, buildings, stones, sea, birds and plants around us. To feel fully alive, we need to feel our interconnection with all life around us – our intimate interdependence with the human and the more than human world.

Our role as change agents in the transition towards a permanently transforming and evolving culture of sustainability is to aim to integrate human systems into the regenerative cycles of nature by design. To do this successfully we have to become apprentices of nature's wisdom again; realise our fundamental interconnection with the patterns, networks and cycles by which "life creates conditions conducive to life" (see Janine Benyus); and humbly aim to co-design regenerative systems based on symbiosis and cooperation within both the human family and the family of life as a whole.

The impulse behind Permaculture is to provide tools for people to promote their creativity and power to build a better future. To this end the Permaculture movement's greatest achievement is probably the creation of a self-developing global network of Permaculture teachers that share best practices. Its ideas about food production are focussed on imitating natural systems with their innate stability but low productivity and then finding ways to increase that productivity. Organic farming by contrast has tended to take the very productive but less stable agricultural systems that exist and try to build more stability into them. For example, Permaculture tends to suggest mixed species cropping whilst organic farmers achieve biological diversity more through crop rotation so that they can keep the high labour productivity achieved by growing larger areas of one crop.

The Ethical Foundations of Permaculture Design and its Biomimetic Attitude

According to Bill Mollison and Reny Mia Slay, 1994, "Permaculture is about designing sustainable settlements. It is a philosophy and an approach to land use, which weaves together microclimate, annual and perennial plants, animals, soils, water management, and human needs into intricately connected, productive communities". This definition resulted in decades of research by Bill Mollison and David Holmgren, commencing in the 70s, in response to soil, water and air pollution by industrial and agricultural systems, loss of plant and animal species, reduction of natural, non-renewable resources and destructive economic systems. They reassembled old wisdoms, skills and knowledge of plant, animal and social systems while adding new ideas – and Permaculture was born.

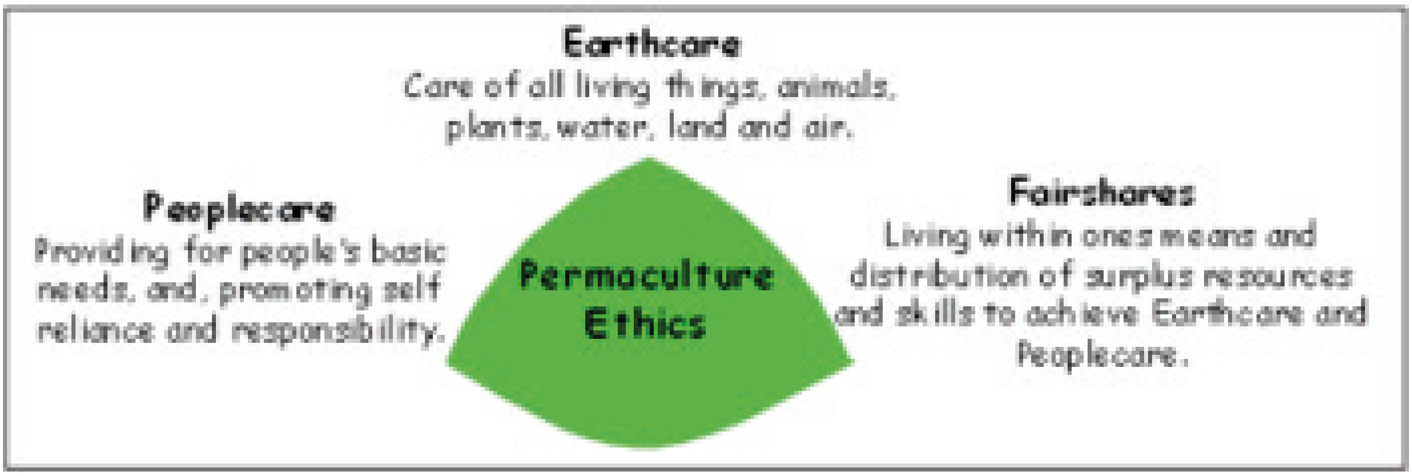


Figura 3.2a: Permaculture Ethics

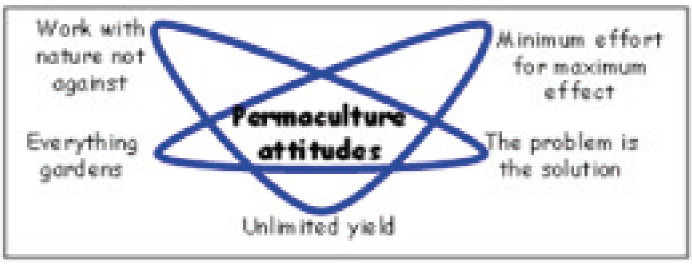


Figura 3.2b: Permaculture Attitudes

Although many aspects of Permaculture were familiar, it was the overall interlocking pattern which was different. Unlike other modern agricultural systems, Permaculture – has been placed squarely on the shoulders of ecology - the study of interrelationships and interdependence of living things and their environment. While many traditional agriculture systems also have co-evolved with natural systems and aimed to adapt to and learn from their patterns and cycles, permaculture has a more scientific underpinning of ecology as the whole systems discipline of biological sciences. Permaculture is informed by what we know about how life works. The result is Permaculture's underlying intention to find a new way of sustaining and enriching life without environmental and social degradation. The foundation of Permaculture are its interrelated Ethics, which straddle all political divides, all racial barriers, and all cultural differences, as reflected in **Figure 3.2a**.

Supporting the Permaculture Ethics are the Permaculture Attitudes (see **Figure 3.2b**), which provides a critical eye for lateral thinking out of the box instead of treading the usual conventional mainstream. For example, a favourite quote is: “one does not have a slug problem, but rather, a duck deficiency”, to explain “the problem is the solution”. “Everything gardens” implies that all living beings affect their environment one way or another. Once we understand this, we can choose to have a regenerative rather than a degenerative influence on the systems in which we participate. If we choose regeneration as the goal, we have to learn to think and design like Nature. The Principles of Ecoliteracy, the Life’s Principles of biomimicry, or the Principles of Permaculture all aim to offer guidance to those who aim to design with and as nature.

1. **It is a system** for creating sustainable human settlements by integrating design and ecology.

2. **It is a synthesis** of traditional knowledge and modern science, applicable to both urban and rural situations.
3. **It takes natural systems** as a model and works with nature to design sustainable environments, which will provide basic human needs as well as the social and economic infrastructures which support them.

4. **It encourages us to become a conscious** part of the solutions to the many problems which face us, locally and globally.

Permaculture Design Principles

The Permaculture Design Principles are based upon a holistic and integrated approach to sustainable design solutions. Co-founder of the Permaculture concept, David Holmgren, has developed these Design Principles in great depth in his book, “Permaculture – Principles and Pathways Beyond Sustainability”.

*The principles and ethics are summarised in **Figure 3.2c,** and explained by David Holmgren in this vídeo. He stresses that applying just one of these principles on their own could create problems, the art of good Permaculture is to be informed by a whole systems thinking approach creating integrated design solutions inspired by these principles.*

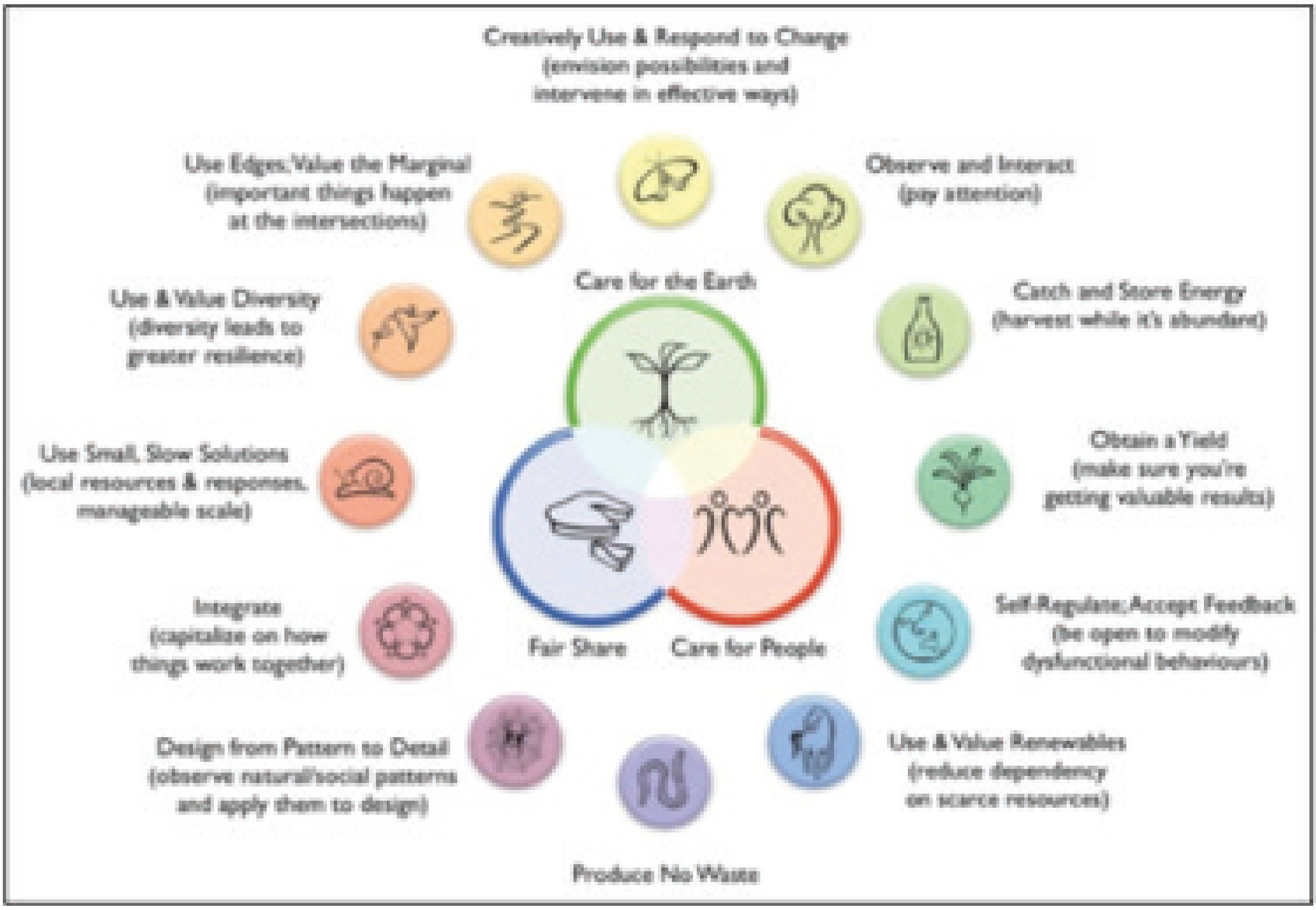


Figure 3.2c: *Permaculture design principles, by David Holmgren*

Permaculture Design Tools

Holmgren's Permaculture Design Principles augment the Permaculture Design Tools outlined in Table 3.2a. The Energy Efficient Planning criteria informs the basic framework of a Permaculture design scheme; the Resource Planning components inform how resources are harvested and integrated into a scheme; whilst the Design Planning items influence how the scheme is assembled and compiled.

Energy Efficient Planning	Resource Planning	Design Planning
Zone planning	Multiple function	Multiple function
Elevation planning	Multiple element	Maximise edge
Sector planning	Energy recycling	Succession
	Biological resource	Diversity
		Pattern

Table 3.2a: *Permaculture Design Tools*

Permaculture Design Principles

A key concept in Permaculture design is zone planning. The concept of Permaculture zones for a typical homestead (see **Figure 3.2d**) can easily be stretched to cover related more expansive zones for a village or town, as outlined in **Table 3.2b**.

Zone	Permaculture zones for homesteads	Permaculture zone for villages and towns
Zone 00	The individual	The people
Zone 0	Home dwelling	Village green and town square
Zone 1	Domestic self-sufficiency - pick and pluck plants for daily usage	Social self-sufficiency - commercial, public and entertainment facilities
Zone 2	Small animal stock and orchards	Dwellings and homestead gardens
Zone 3	Crops, forage and stored food	Agricultural allotments
Zone 4	Gathering, forage, forestry and pastures	Orchards and passive open space
Zone 5	Natural environment	Natural environment

Table 3.2a: *Permaculture Design Tools*

3.3 Organic Farming

While it has been often celebrated for how it helped to feed a rising population of human beings, the so called Green Revolution of large scale industrial agriculture with its addiction to fossil resources and its systematic degradation of local farming communities and biocultural diversity in favour of predatory multinational corporations, has turned out to be a failure with disastrous effects. Alternatives do exist. The Soil Association in the UK was started in 1946 and the Rodale Institute in the USA in 1947; both institutions promote and develop organic farming approaches.
The Soil Association is an environmental charity promoting sustainable, organic farming and championing human health.
The International Federation of Organic Agriculture Movements (IFOAM) is the worldwide umbrella organisation for the organic movement. From their website, "Our mission is 'leading change, organically'. This means that we work toward true sustainability in agriculture, from the field, through the value chain to the consumer. With more than 750 members in over 127 countries, we are the voice of the global organic movement". (Source: IFOAM). See also the IFOAM Principles of Organic Agriculture, which turn out to be remarkably similar to the Permaculture ethics, as well as, the Best Practice Guidelines for Agriculture and Value Chain, as depicted in **Figure 3.3.**

In different European languages organic agriculture is often also called biological or ecological agriculture (as opposed to the industrial high chemical and fossil fuel input variety). Over the last fifty years, organic agriculture has developed into a well-codified set of principles and practices. IFOAM expresses the aims of organic farming as follows:

- **To produce food** of high nutritional quality in sufficient quantity;
- **To work with natural systems** rather than seeking to dominate them;
- **To encourage and enhance** biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals;
- **To maintain and increase** the long-term fertility of soils;
- **To use, as far as possible,** renewable resources in locally organised agricultural systems;
- **To work as much as possible** within a closed system with regard to organic matter and nutrient elements;
- **To give all livestock conditions** of life that allow them to perform all aspects of their innate behaviour;
- **To avoid all forms of pollution** that may result from agricultural techniques;
- **To maintain the genetic diversity** of the agricultural system and its surroundings, including

the protection of plant and wildlife habitats;

- **To allow agricultural producers** an adequate return and satisfaction from their work, including a safe working environment;

- **To consider the wider social** and ecological impact of the farming system.

Figure 3.3: Best Practice Guidelines for Agriculture and Value Chain [*Image Source*]

3.4. Holistic Management

The contribution of the Zimbabwean born Allan Savory to Holistic Management provided two major components to Regenerative Agriculture. Firstly, it's the holistic whole systems context for a farming initiative, and secondly, it's the biomimicry approach of emulating the grazing of wild herds by domesticated livestock. Savory correctly postulated that the desertification of the Sub Saharan Sahel, and other similar areas, is not the result of overgrazing, but rather, grazing mismanagement, and in particular, insufficient grazing animals and predators. In the wild, herds are forced to mob graze together for fear of predators, which keeps the herd tightly together, thereby grazing everything uniformly in an area plus stomping their manure and urine into the soil. That is, until predators start hunting those members of the herd that stray or who are more vulnerable, such as, the lame, wounded, elderly or youngsters. The hunting predator forces the herd away to another area where the process is continuously repeated.

One can predict what happens when predators are eradicated: herds graze the choosiest grasses indiscriminately anywhere leaving the hardier grasses to grow into thick clumps around which surface erosion takes place when it rains. The lack of uniform ground cover and the resistance of grass clumps exacerbates soil erosion which leads to desertification. This is exactly what happens with domestic livestock whose grazing is not managed.

From this analysis, the simple solution is to mimic the function of predators by means of mobile electric fences which forces domestic livestock to mob graze specific areas uniformly until the grass is exhausted before moving the mobile electric fence to the next grazing area. The stocking densities of livestock in short cycle-controlled mob grazing are significantly higher

Holistic Management has the potential to become a game-changer for climate change mitigation, as Savory explained in his 2013 video (20 minutes) titled, "How to green the world's deserts and reverse climate change". Savory's tried and tested practices led to the establishment of Holistic management and its associated technique of "holistic mob grazing" (see the video), 3:25mins), also known as "mob grazing", are based on a systems thinking approach that mimics nature.

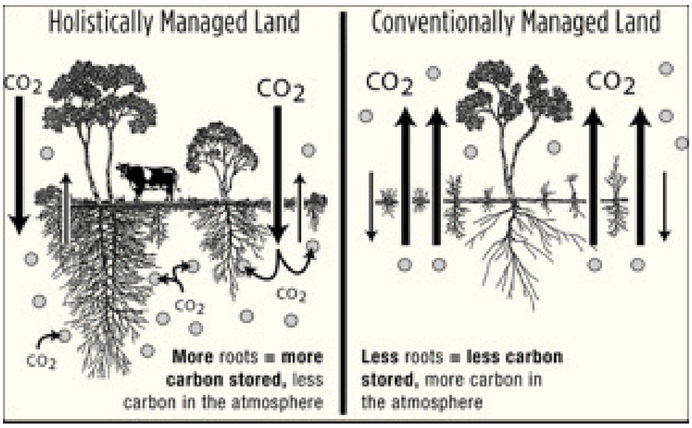


Figure 3.4: A comparative illustration of Holistically and Conventionally Management Land

than those of free range uncontrolled grazing. Controlled mob grazing is thus able to reverse desertification, restore grasslands and increase the livestock carrying capacity of grassland by mimicking the nutrient closed loop cycle that occurs in nature as illustrated in **Figure 3.4**.

The Savory Institute has become a well-established entity with a growing global network of educational / demonstration hubs, trained land managers and validated holistically managed land. They also conduct and participate in research about holistic management and also have a repository of related published information.

In a 2015 article, the Savory Institute suggested that Holistic Planned Grazing could be applied to approximately 5 billion hectares of the world's degraded grassland soils in order to restore them to optimal health and thereby sequester more than 10 gigatons of

Watch this video (4mins) of Allan Savory explaining his vision of ***Changing our Future****.*

atmospheric carbon annually into the soil's organic matter, "thereby lowering greenhouse gas concentrations to pre-industrial levels in a matter of decades. It also offers a path towards restoring agricultural productivity, providing jobs for thousands of people in rural communities, supplying high quality protein for millions, and enhancing wildlife habitat and water resources".

3. Whole Systems Approach

3.5. Agro-ecology, Agro-forestry and Food Forests

Agroecology

Agroecology is "the application of ecology to the design and management of sustainable agroecosystems." It takes "a whole-systems approach to agriculture and food systems development based on traditional knowledge, alternative agriculture, and local food system experiences." It links "ecology, culture, economics, and society to sustain agricultural production, healthy environments, and viable food and farming communities" and vernacular architecture are all valuable expressions of the 'spirit of place' in a given location and can inform restorative design.

Agroecology, as promoted by Miguel Altieri (1995) is very much aligned with the shift towards a regenerative agriculture. Altieri has done important work on the preservation of indigenous agricultural knowledge and techniques while working for the UN's Food and Agriculture Organization (FAO) on Globally Important Agricultural Heritage Systems (Koohafkan & Altieri, 2010).
The FAO of the UN defines the 10 elements of

agro-ecology as:

- **Diversity; synergies; efficiency; resilience;recycling; co-creation and sharing of knowledge** (describing common characteristics of agroecological systems, foundational practices and innovation approaches)

- **Human and social values;** culture and food traditions (context features)

- **Responsible governance;** circular and solidarity economy (enabling environment)

The 10 Elements of Agroecology are interlinked and interdependent. And it links them to achieving the Sustainable Development Goals

In Europe, agro-ecology is often used as an umbrella term for a whole range of agricultural practices that aim to mimic natural ecosystem processes according the conditions of the local biome: no till / no dig with cover crops, agro-forestry and silvopasture, Permaculture and food forestry can all be regarded as agro-ecological practices.

Agroforestry

Agroforestry stands to become one of the most important practices in our striving for food systems resilient to global warming as well as ecosystem restoration and carbon sequestration.

In places where the natural biome is open-canopy woodland, as for example in large parts of Europe, the Americas and Africa, agro-forestry practices are traditional. Essentially, it is the practice of deliberately integrating woody vegetation (trees and/or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions. In Southern Europe, for example, polycultures of productive trees,

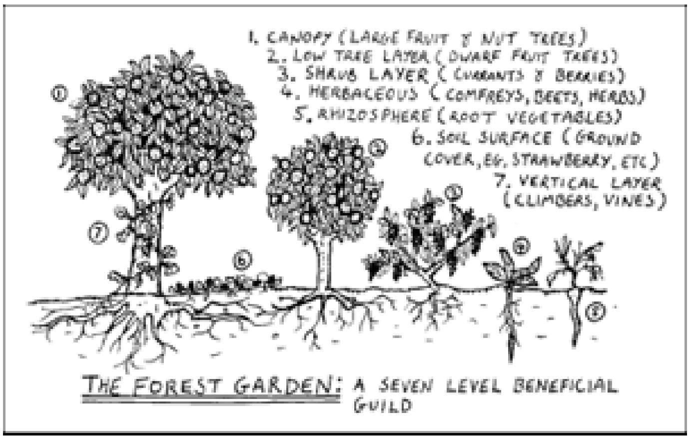


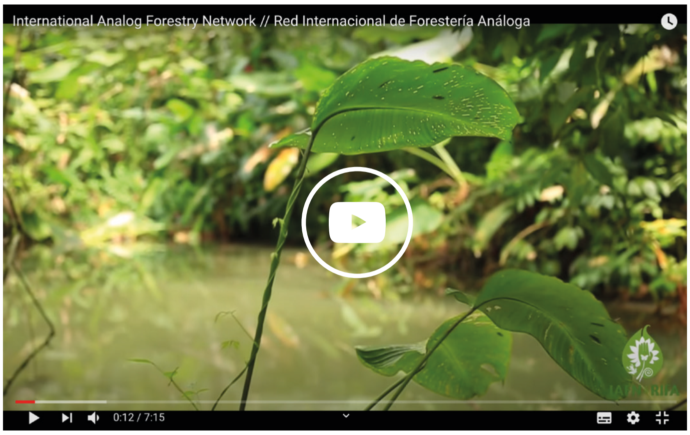
Figure 3.5a: The Forest Garden – a seven level beneficial guild (source)

- *'**Canopy layer**' consisting of the original mature fruit trees.*
- *'**Low-tree layer**' of smaller nut and fruit trees on dwarfing root stocks.*
- *'**Shrub layer**' of fruit bushes such as currants and berries.*
- *'**Herbaceous layer**' of perennial vegetables and herbs.*
- *'**Rhizosphere**' or '**underground**' dimension of plants grown for their roots and tubers.*
- *'**Ground cover layer**' of edible plants that spread horizontally.*
- *'**Vertical layer**' of vines and climbers.*

such as fruits and nuts are still being combined with pigs, poultry and cattle. In Northern Europe, extensive grazing and silvopasture that combines woodlands with cattle, pigs and goats is a practice that goes back thousands of years and utilises the way all ungulates (hooved animals) maintain the health of the open canopy that allows under-growth to thrive. The browsers taste for woody shrubs that keep unwanted elements of undergrowth under control also ensures food supplies for the animals in winter. These practices have been marginalised by the subsidy systems that favour large-scale monocultures, but are being revived, sometimes with startling results in terms of regeneration.

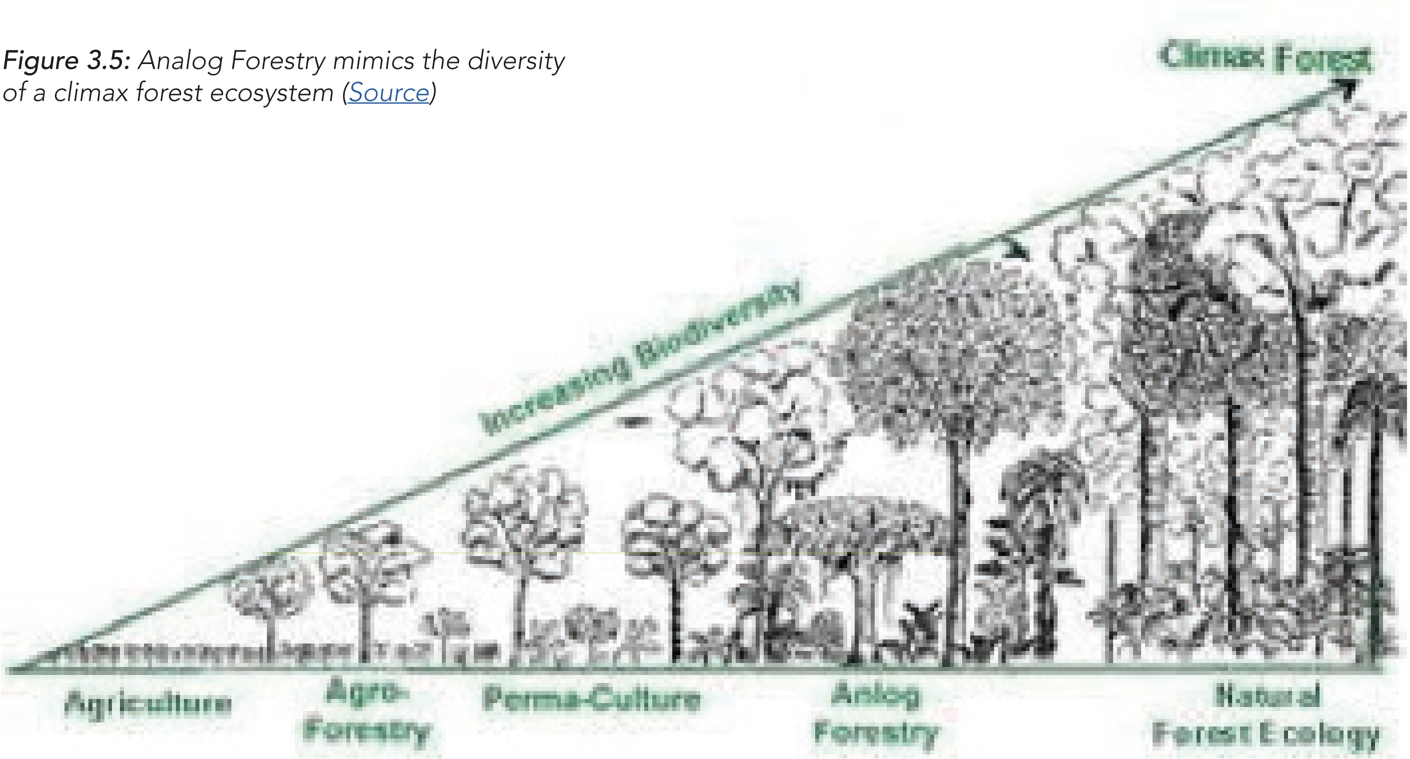
The technique of 'forest gardening' is a prehistoric method of food production in many tropical areas. Robert Hart pioneered 'forest gardening' in temperate climates and his work has been taken up and developed further by Patrick Whitefield and Martin Crawford, who runs the Agroforestry Research Trust. Robert Hart transformed his existing small orchard into an edible polyculture landscape by intercropping into the following layers which are illustrated in **Figure 3.5a.**

The related approach of 'Analog Forestry' uses "natural forests as guides to create ecologically stable and socio-economically productive landscapes". This whole-systems approach to silviculture "minimizes external inputs, such as agrochemicals and fossil fuels, instead fostering ecological function for resilience and productivity". Ranil Senanayake developed the 'Analog forestry' approach in Sri Lanka in the early 1980s. It has since grown into a global network of practitioners with a standard for certified 'Forest Garden Products' (International Analog Forestry Network (IAFN), 2015).



This video (7mins) shows how Analog Forestry is spreading in Latin America, Asia, Africa and around the world.

Figure 3.5: Analog Forestry mimics the diversity of a climax forest ecosystem (Source)



3.6. Syntropic Agriculture

Syntropic Agriculture was established by Ernst Götsch, whose search for the opposite of entropy in living systems led him to the complementary concept of syntropy. Whilst entropy is associated with energy dispersal, divergence and simplification, syntropy is associated with energy concentration, convergence and complexity. Entropy and syntropy are complementary, as in the example of wood, a complex form, which when burnt, breaks down to embers, ash and smoke / gasses, which in turn, become ingredients to recombine with living matter, soil, to form yet another level of complexity, and so on.

Götsch noted that industrial agriculture is an entropic linear system which uses Nature's resources indiscriminately, and when exhausted, replaces them with synthetic chemicals, thus effectively "mining soil". Instead, through keen observation, trials and refinements, Götsch has mimicked Nature's cycles and growth spurts between the interface of entropy and syntropy, thereby developing the closed system concept of Syntropic Agriculture. Syntropic Agriculture is also based on Permaculture principles, but whilst the latter focuses on a whole farm systems design, Syntropic Agriculture makes a specific contribution towards food forests and agro-forestry through ecosystem regeneration. According to Götsch:

"In Syntropic Farming, holes become nests, seeds become genes, weeding becomes harvesting, the competition gives way to cooperation and pests and diseases are seen as the "agents from the department of optimization of life processes". These and other terms do not arise by chance, but rather derive from a change in the way we see, interpret and relate to nature. Many of the sustainable farming practices are based on the logic of input substitution. Chemicals are replaced with organic, plastics with biodegradable materials, pesticides with all sort of preparations. However, the way of thinking is still very close to that one they oppose. In common, they combat the consequences of the lack of adequate conditions for healthy plant growth. Syntropic Agriculture, on the other hand, helps the farmer replicate and accelerate the natural processes of ecological succession and stratification, giving each plant the ideal conditions for its development, placing each one in their "just right" position in space (strata) and in time (succession). It is process-based agriculture, rather than input-based. In that way, the harvest is seen as a side effect of ecosystem regeneration, or vice versa".

***Ernst Götsch**, Source*

The FAO has included Syntropic Agriculture in its Agroecology Knowledge Hub and deployed this system in some of Mozambique's degraded areas (see links one and two).

This is a video (16 mins) about Syntropic Agriculture that was made especially for the Paris COP21 in 2015.

This video (2 mins) documents the impressive implementation of a project in just a few months.

3.7 Regenerative Agriculture

The term Regenerative Agriculture is a fairly recent term which emerged when a team of Regrarians combined several systems of sustainable agriculture. In this combination, Permaculture lays out the intrinsic design principles; the Yeomans Scale of Permanence (Keyline System) outlines the design sequence for these principles; and, Holistic Management provides the fundamental understanding of the whole integrated system, including the mob grazing methodology. All the other sustainable agricultural methods are merely subsets of these three main influences of Regenerative Agriculture, namely, Permaculture, the Keyline System and Holistic Management. According to http://www.regenerativeagriculturedefinition.com/, Regenerative Agriculture is:

- **a system of farming principles and practices** that increases biodiversity, enriches soils, improves watersheds, and enhances ecosystem services;
- **it aims to capture carbon in soil** and aboveground biomass, reversing current global trends of atmospheric accumulation; and,
- **it simultaneously offers increased yields**, resilience to climate instability, and higher health and vitality for farming and ranching communities.

The design sequence for Regenerative Agriculture from the Regrarians team is outlined in Figure 3.8 with the components comprising the following layers of information that is accumulated until a regenerative farm design is complete, whether it is for a new or retrofitting an existing farm:

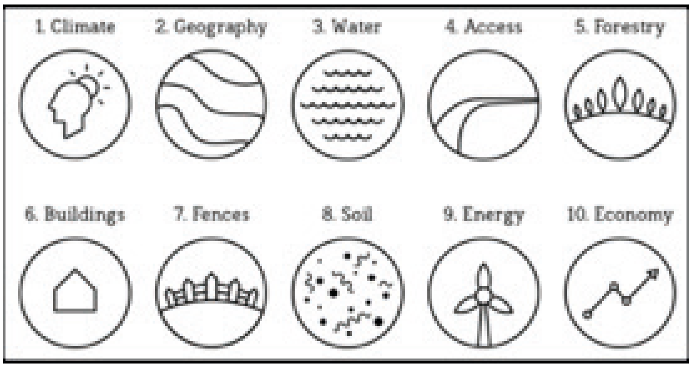


Figure 3.8: Regrarians design sequence

- **Climate:** This first component assesses the farmer, the farm enterprise, the weather, risk issues, and, provides the strategic framework for holistic management.
- **Geography:** This assesses the shape of the landform (valleys, ridges, riparian, special features, etc.); the components on the land (farm facilities, infrastructure, utilities, buildings; and, the proximity to towns, markets, labour, etc.
- **Water:** This is the design of landscape-based rainwater harvesting; water storage in catchment and other dams; and, water reticulation for irrigation.
- **Access:** This is an assessment of and design integration of water with road, track and foot access; delineation of servitudes for utilities and other farm infrastructure; and, access to consumers and markets.
- **Forestry:** This entails the design integration with water and access in order to establish biodiverse forest shelter belts which provide the micro-climates for cultivation, grazing, orchards, riparian or wilderness areas.

- **Buildings:** This component identifies the ideal locations for or the retrofitting of homesteads, sheds, facilities, etc.

- **Fencing:** This entails the planning and installation of permanent, mobile, electric or living fences that facilities livestock-controlled mob grazing.

- **Soils:** This component provides the management process for livestock-controlled mob grazing; limited till plans; enhancement of soil minerals and fertility; and, the rotational cultivation plan of crops.

- **Economy:** This entails the market analysis, strategy, value chain and enterprise development for a diverse income stream in order to create economic resilience.

- **Energy:** This component establishes off-grid energy systems for the operation of the farm from sources such as, solar, wind, micro-hydro, woodlots, biomass, etc.

Some of the key features of Regenerative Agriculture are explored in the next section in order to appreciate their input in the above design sequence.

4. Application of Sustainable Design Solutions

Context

This section builds upon the theoretical whole systems approaches to sustainable agriculture described in the earlier section by exploring a few relevant applications of design solutions. In particular, this section will look at how various systems are integrated as steppingstones towards a design process. The contents of this section initially describe some broader design integration concepts and then some individual concepts that can be integrated within broader context, namely:

- **Land restoration** through rehabilitation of riparian zones
- **Landscape-based** rainwater harvesting
- **Drought-, flood- and fire-proofing** landscapes
- **Food** Forests
- **Limited Till** with Yeomans Keyline Plow
- **The Importance** of Perennial Crops
- **Seasonal** cultivation
- **Aquaponics**
- **Mycorestoration**
- **Vetiver** Systems
- **Biochar**
- **Seedballs**

4.1 Land restoration through rehabilitation of riparian zones

A fully functional riparian zone alongside gullies, streams and rivers provides an essential ecosystem service for very little cost. However, once the biomass of trees and shrubs are removed from a riparian zone, the sheet flow of rainfall flows unchecked into water courses together with topsoil which is flushed downstream. Eventually, these water courses become deeply scoured through erosion which unfortunately results in the water table being lowered in lands adjacent to the water course, often with drastic consequences for trees and crops whose roots no longer reach the water table. Droughts are thus exacerbated through the removal of riparian zones and resulting erosion of water courses. The simple

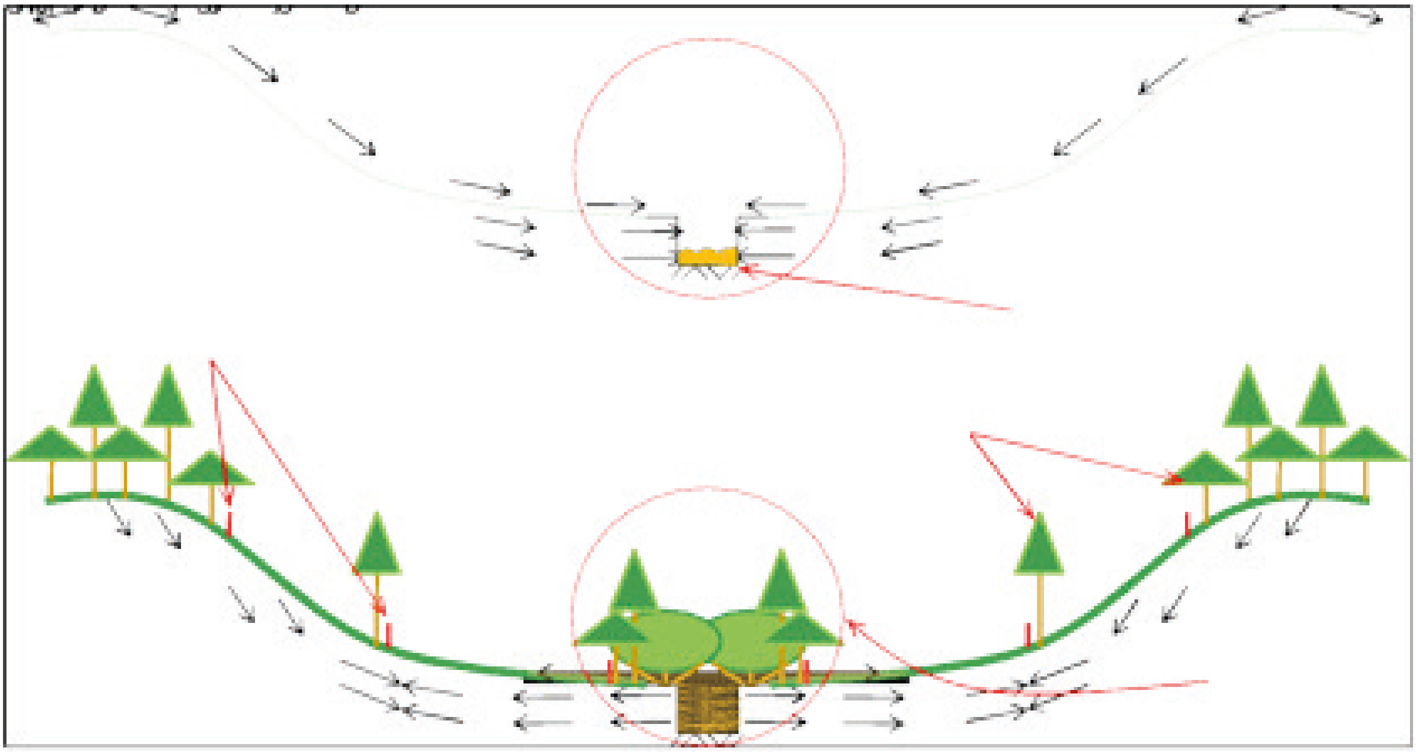


Figura 4.2: *O processo de reabilitação de uma zona ripária com barrancos atingidos por erosão.*

rehabilitation of riparian zones and restoration of water courses through incremental check weirs can raise and replenish the water table thus benefitting the adjacent lands as illustrated in **Figure 4.2**. The benefits from the rehabilitation of riparian zones can be summarised as follows:

- **It acts as a buffer** to reduce flooding and erosion.
- **Stormwater surface** flows are slowed down, spread and sunk into the groundwater.
- **It acts as a filter** to trap silt and absorb harmful chemicals from entering the water course.
- **It provides biodiversity** and habitat for wildlife as well as for the aquatic environment.
- **It provides a wilderness** area for people to appreciate.

4.2. Landscape-basedrainwater harvesting

The most important design component of Regenerative Agriculture is for water. Herein the Keyline System defines the process of designing landscapes which can harvest their entire water supply needs from the inherent characteristics of the land formation, similarly, referred to as the Natural Capital. The Keyline System identifies points of inflection or Keypoints in valleys where the slope changes from convex to concave, thus highlighting zones where water discharges down valleys slows down, siltation occurs and clay soils develop, thus making ideal opportunities for catchment dams. The Keypoints in turn determine the Keyline contour swales. The ensuing base map of Keypoints and Keyline contour swales is analysed so that a design is created with interconnecting catchment dams and swales designed to suit specific gradients so that the overflow from one catchment dam can feed lower catchment dams. In this manner, rainwater is channelled onto ridges thereby rehydrating landscapes that would otherwise not benefit from such rainfall infiltration. An illustration of the water design for the Keyline System is shown in Figure 4.3 which shows a typical farm landscape as "undeveloped" and "enhanced" Natural Capital. The dams shown in this figure also have outlets at the base of the earthen dam wall for use as irrigation along swales.

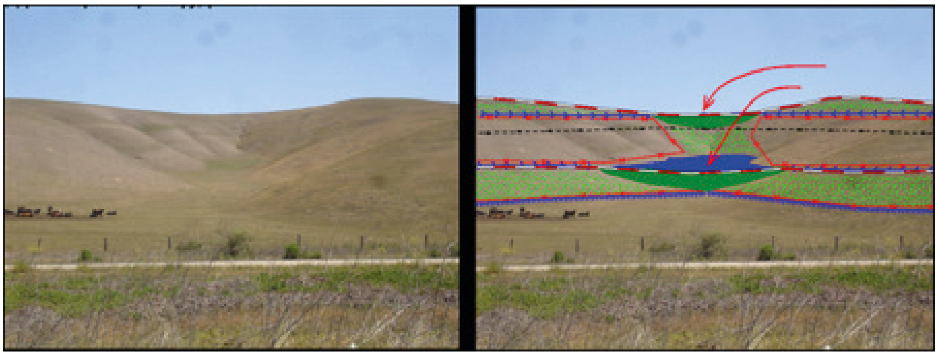


Figure 4.3: An example of Keyline System design for water

Desertification and this requires methods of reforestation, ecosystem restoration and changes to agriculture that are appropriate for the local biome. Maximising the soil organic carbon facilitates rainwater retention and restores the natural carbon, hydrological and nutrient cycles (see module 3). Restoring land through community action is the most effective and can also add to achieving a number of Sustainable Development Goals.

PA Yeomans developed the Keyline System on his farm, Yobarnie (see Plate 4.3), in a semi-arid area of Australia that received an average 350mm rainfall per annum. By the time Yeomans had established the series of catchment dams and interconnecting swales, the combined surface area of all the dams was approximately 15% of the total farm area. Yeomans totally transformed his farm so that the annual rainfall was more than sufficient to farm productively. This feature highlights the importance of establishing small catchment dams or detention ponds throughout the farm landscape in order to rehydrate soils and thereby recharge the underlying water table.

Plate 4.3: Yeomans' farm, Yobarnie, Australia

4.3. Drought-, flood- and fire-proofing landscapes

The integration of Water, Access and Forestry in the Keyline System provides an instant solution for effectively drought-, flood- and fire-proofing landscapes. This is possible due to the swale which slows, spreads and sinks rainwater, thereby both drought- and flood-proofing the landscape. The swale also creates a water plume in the soil downslope from the swale. This water plume in turn facilitates a forest belt, which adds to biodiversity, provides a habitat for pollinating insects, acts as a shelter-belt and wind-break. A forest-belt of diverse indigenous trees is unlikely to burn, as opposed to a monoculture plantation, thus providing the fire-proof barrier. This concept is illustrated in **Figure 4.4**, wherein the swales are sometimes expanded into hugelkultuurs, whilst the benefits from this concept are outlined below:

- **Promotes** rainwater harvesting
- **Re-charges** water tables
- **Reduces** need for irrigation
- **Mitigates** against soil erosion
- **Provides** windbreaks that reduces wind burn, creates beneficial micro-climates and contributes to biomass
- **Draws up** vital minerals for plant use
- **Improves** biodiversity
- **Improves soil humus** which sequestrates CO2 that mitigates against Climate Change.

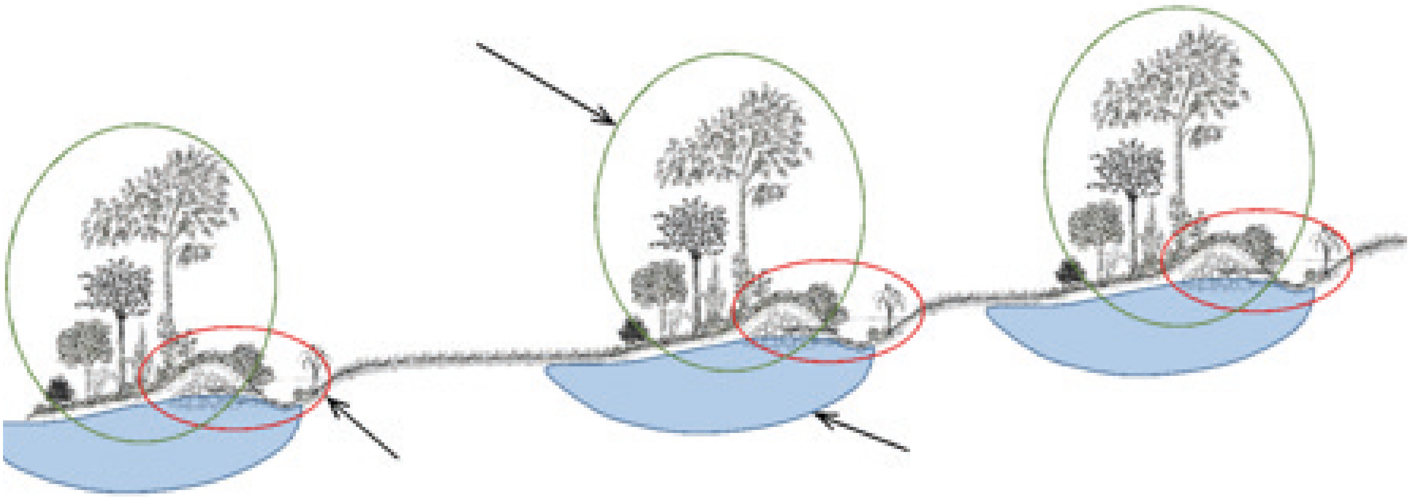
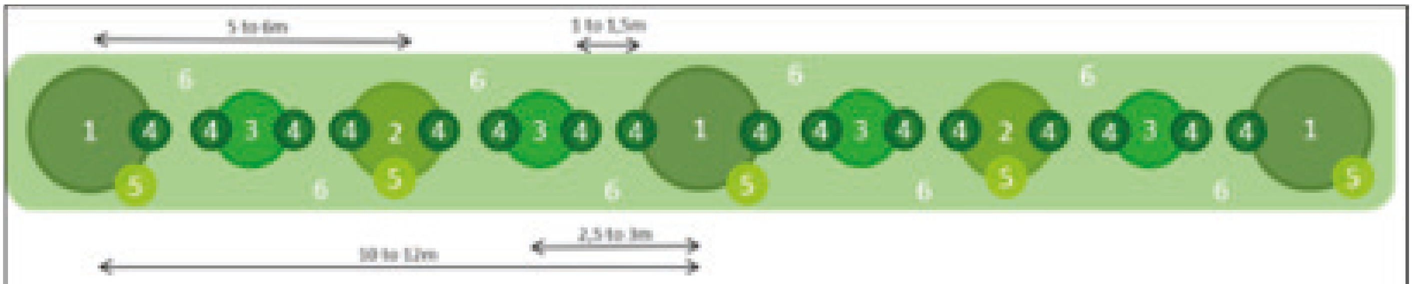


Figure 4.4: An illustration of swales and forest belts

4.4. Food Forests

According to the FAO, agroforestry is collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. This can take the form of a fully-fledged food forest or individual species. An example of a food forest strip with a specific planting pattern that mimics a natural forest is shown in **Figure 4.5**, which also suffices as a shelter-belt forest strip.



A 20 to 24m length of a Swale Type 1 or Type 2 will have 2 of ❶ Upper Canopy Trees; 2 of ❷ Mid-Canopy Trees; 4 of ❸ Under Storey Trees; 16 of ❹ Shrubs; 1 or 2 ❺ Climbers; and 60 to 72m² of ❻ Groundcover for Swale Type 1, and, 30 to 36m² of ❻ Groundcover for Swale Type 2.

Level	Tree / Plant Types
❶	**Upper Canopy Trees:**- Avo, Mango, Jakfruit, Sclerocarya birrea Marula, Syzyguim cordatum, Inga edulis, Pecan, Sclerocarya birrea Marula, Albizia, Acacia albida, Erythrina caffram, Milletia grandis, Manilkara, Balanites, Rhus chirendensis, Vepris and Yellowwood.
❷	**Mid-Canopy Trees:**- Lychee chirindensis, Orange, Carob, Harpephyllum caffrum, Macadamia nut, Pachira Nut, Calpurnia aurea, Erythrina lysistemon, Trema orientalis and Berchemia.
❸	**Under Storey Trees:**- Lemon, Grapefruit, Kamquat, Fig, Pomegranate, Tree tomato, Persimmon, Ximenia caffra, Dovyalis caffra, Vangueria infausta, Diospyros lycriciodes, Deinbollia oblongifolia, Sesbania sesbans, Craibia zimmermanii, Indigofera juncunda, Schotia bracepetala, Ximenia caffra and Bracylaena discolour.
❹	**Shrubs:**- Carissa macrocarpa, Cassava, Pricky Pear, Pigeon Pea, Sunflower, Sunnhemp, Rosemary, Lavender, Chillies, Coffee, Bauhinia galpinii, Bauhinia tomentosa, Tephrosia, Polygala, Shellbush, Wormwood and Buddleja saligna.
❺	**Climbers:**- Grapes, Quavadilla and Grandilla.
❻	**Groundcover:**- Cowpeas, Edemame, Lablab, Alfalfa, Fenugreek, Lupin, Clover, Field Peas, Bushbeans, Marigold, Calendula, Tulbaghia, Aptenia cordifolia and Carpobrotus sour fig.

Figure 4.5: An example of a sub-tropical planting plan for a forest strip

4.5. Limited Till with Yeomans Keyline Plow

Besides Yeomans Scale of Permanence or the Keyline System, PA Yeomans also developed a limited till plow which he called Yeomans Keyline Plow as shown in the Plate 4.6 collage. This type of Keyline plow has been successfully used to rehabilitate arid farmland which has lost its soil fertility through too much tillage. Furthermore, this limited till-type technology is a key component for sustainable agriculture for the following reasons:

- **It ensures** minimum soil compaction
- **It aerates soil** and facilitates ingress of water
- **It provides** a micro-climate for a vigorous growth start of crops
- **It minimises soil** disturbance for micro-organisms
- **It promotes** the growth of organic carbon (humus) to deeper soils
- **It promotes** greater retention of soil moisture through organic carbon
- **It promotes** greater carbon sequestration from the growth of organic carbon
- **It promotes** soil fertility and biodiversity
- **It has relatively lower costs** than conventional agriculture

The real benefits of the Keyline Plow is its application with the Keyline System of landscape-based rainwater harvesting. Herein, the Keyline contour swale plays a pivotal role in determining the pathways of the Keyline plow. More specifically, in moving parallel to the Keyline contour swale, the shanks of the Keyline plow drill open and aerate avenues for water to seep into the soil and simultaneously drain water across the contours from valleys where soil moisture is abundant, to ridges where soil moisture is lacking as illustrated in **Figure 4.6**.

Plate 4.6: Yeomans Keyline Plow with shank pot seeders

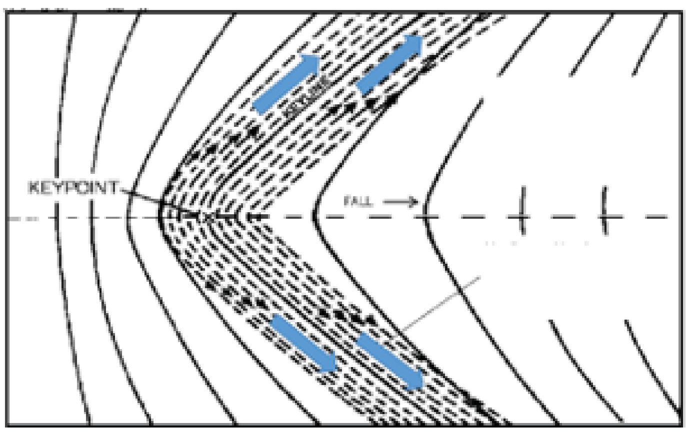


Figure 4.6: Illustration of Keyline plowing

4.6. Seasonal cultivation

According to the FAO, The global food market wherein fruit and vegetables incur extensive food miles, has changed human eating habits and diet as a result of eating out of season. This global food market is reliant on extensive value chain logistics, facilities and infrastructure, all of which results in CO2 food mile emissions. What was once seasonal food is now available anytime, everywhere, worldwide, albeit, with a loss of nutrient vitality, as measured with Brix units. Humans have therefore lost the seasonal taste of food, as well as, the nutritional value of eating freshly harvested fruit and vegetables. One of the key drivers of Regenerative Agriculture is to support local markets by delivering seasonal products.

For seasonal cultivation, farmers need to adopt crop rotation regimes and deploy planting guilds that support and complement each other. An example of crop rotation is shown in **Table 4.7** wherein legumes, which are nitrogen fixing plants, precedes the planting of potatoes, which are heavy soil feeders. The legumes therefore naturally fertilize the soil with nitrogen which is made available to the potatoes.

Figure 4.7: *The "3-sisters" – corn, beans and squash, (source)*

	Year 1	Year 2	Year 3	Year 4
Plot 1	root crops	legumes	potatoes	brassicas
Plot 2	brassicas	root crops	legumes	potatoes
Plot 3	potatoes	brassicas	root crops	legumes
Plot 4	legumes	potatoes	brassicas	root crops

Table 4.7: *An example of a crop rotation regime*

A classic example originating from Central America are the "3-sisters", which is a guild of maize (corn), beans and pumpkins, as shown in **Figure 4.7**. The maize is a heavy feeder, hence the beans, a legume, to provide the nitrogen, whilst the broad leaves of pumpkins maintain a living green cover over the soil in order to retain moisture in the soil. The 3-sisters guild is timeless and does not require any external inputs.

4.7. Aquaponics

Aquaponics is the marriage of aquaculture (raising fish) and hydroponics (the soil-less growing of plants) that grows fish and plants together in one integrated system or closed cycle system. The fish waste provides an organic food source for the growing plants and the plants provide a natural filter for the water the fish live in. The third participants are the microbes (nitrifying bacteria) and red worms that thrive in the growing media. The bacteria do the job of converting the ammonia from the fish waste first into nitrites, then into nitrates and the worms turn the solids into vermicompost. Both are food for the plants. The worms are also food for the fish. In combining both systems aquaponics capitalizes on the benefits and eliminates the drawbacks of each. The closed loop cycle and an example are illustrated in **Figures 4.8a** and **4.8b**.

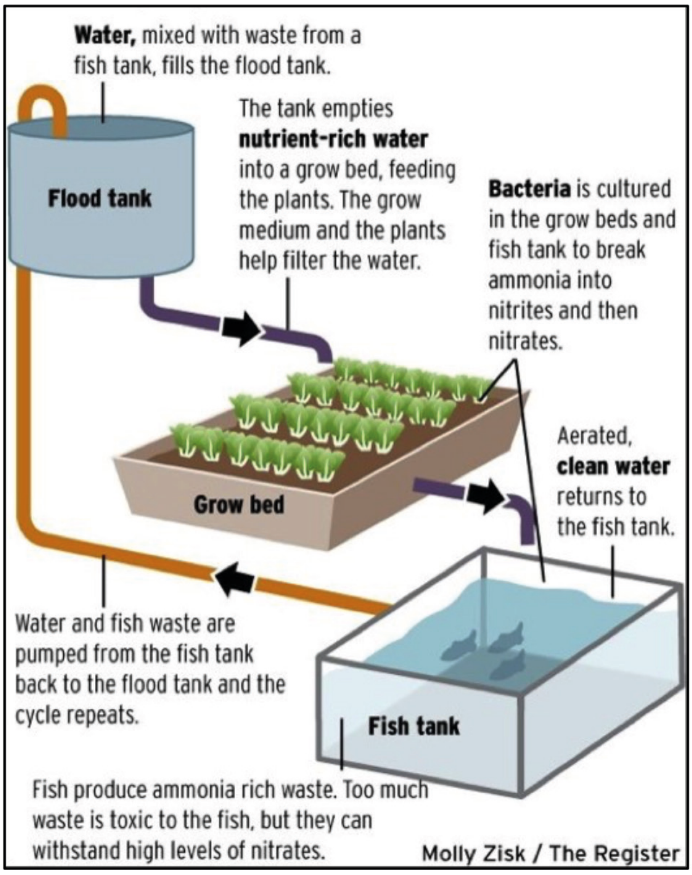


Figura 4.8b: *How Aquaponics works*

Aquaponics can be used on a wide range of scales, from small applications on a balcony in an apartment to a large scale industrial application (more information). Aquaponics also presents a great opportunity to retrofit conventional hydroponic systems dependent on chemical fertilisers to more sustainable systems with an aquaponics component, thereby reducing external input costs, increasing diversity and quality of crops. Source

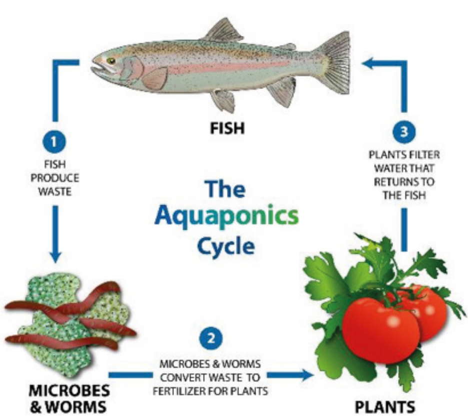
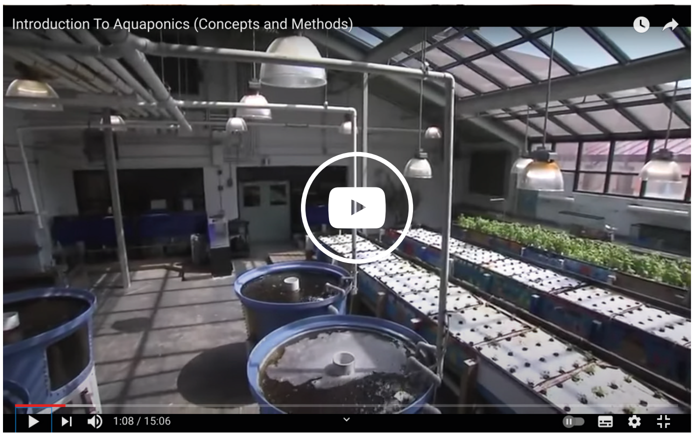


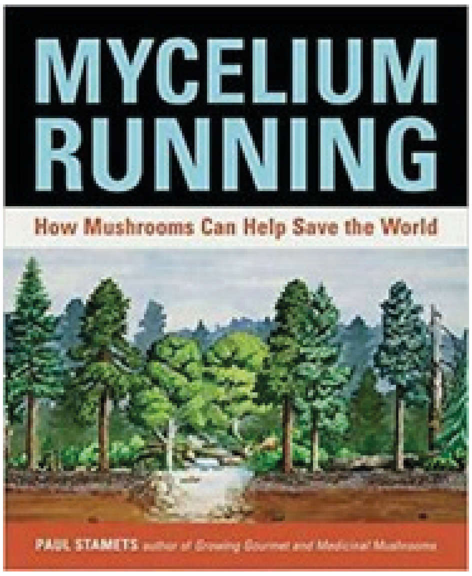
Figure 4.8a: *The Aquaponics Cycle*



There are literally dozens of how-to and short documentary videos on Aquaponic systems on Youtube, Watch this video (15mins).

4.8. Mycorestoration

Leading Mycologist, Paul Stamets, has been a tireless investigator, communicator, innovator and entrepreneur to show how mushrooms can help us to solve complex problems from cleaning polluted soil, making insecticides, treating smallpox and even flu viruses. In his book Mycelium Running: How Mushrooms Can Help Save the World, Paul Stamets (2005) links mushroom cultivation, Permaculture, ecoforestry, bioremediation and soil enhancement, to make the case that mushroom farms can be reinvented as healing arts centers, steering ecological evolution for the benefit of humans living in harmony with our planet's life-support systems and its ecological cycles.



The four components of mycorestoration include:

i. **Mycofiltration:** the filtration of biological and chemical pathogens as well as controlling erosion.

ii. **Mycoforesty and mycogardening:** the use of mycelium for companion cultivation for the benefit and protection of plants.

iii. **Mycoremediation:** the use of mycelium for decomposing toxic wastes and pollutants.

iv. **Mycopesticides:** the use of mycelium for attracting and controlling insect populations.

Stamets has built his company, Fungi Perfecti, into a successful green business and has filed a long list of patents (to protect his innovations against what he calls "the vulture capitalists"). Stamets' work and extensive collection of fungal mycelia will be a critical resource as ecosystem regeneration becomes a central activity for humanity in the 21st Century. A parting quote from Paul Stamets (2005: 55):

"On land, all life springs from soil. Soil is ecological currency. If we overspend it or deplete it, the environment goes bankrupt. In either preventing or rebuilding after environmental catastrophe, mycologists can become environmental artists by designing landscapes for both human and natural benefit."

Here is a link to Paul's TED-talk (17:40mins) that is well worth watching if you are unfamiliar with this field and Paul's work.

4.9. Vetiver Grass Systems

Vetiver grass, Chrysopogon zizanioides, is a unique grass with a long hairy root that anchors the soil and is planted on swales to mitigate soil erosion. Vetiver grass is not an invasive plant and is found in the tropics and subtropical areas, although it also grows fairly well in the temperate zones. Its roots can yield a valued oil. It can be used to create very basic latrines (Vetiver Latrines). The Vetiver System is used extensively for erosion control by the Vetiver Network International.

Vetiver grass has a wide range of applications, namely;

- **Soil and water** conservation (on-farm and off-farm)
- **The stabilisation** of soil related infrastructure, and the containment of sediment from such structures
- **Rehabilitation** of wasted and ecologically damaged sites and the containment of such sites against future disasters
- **Water-pollution** and waste management

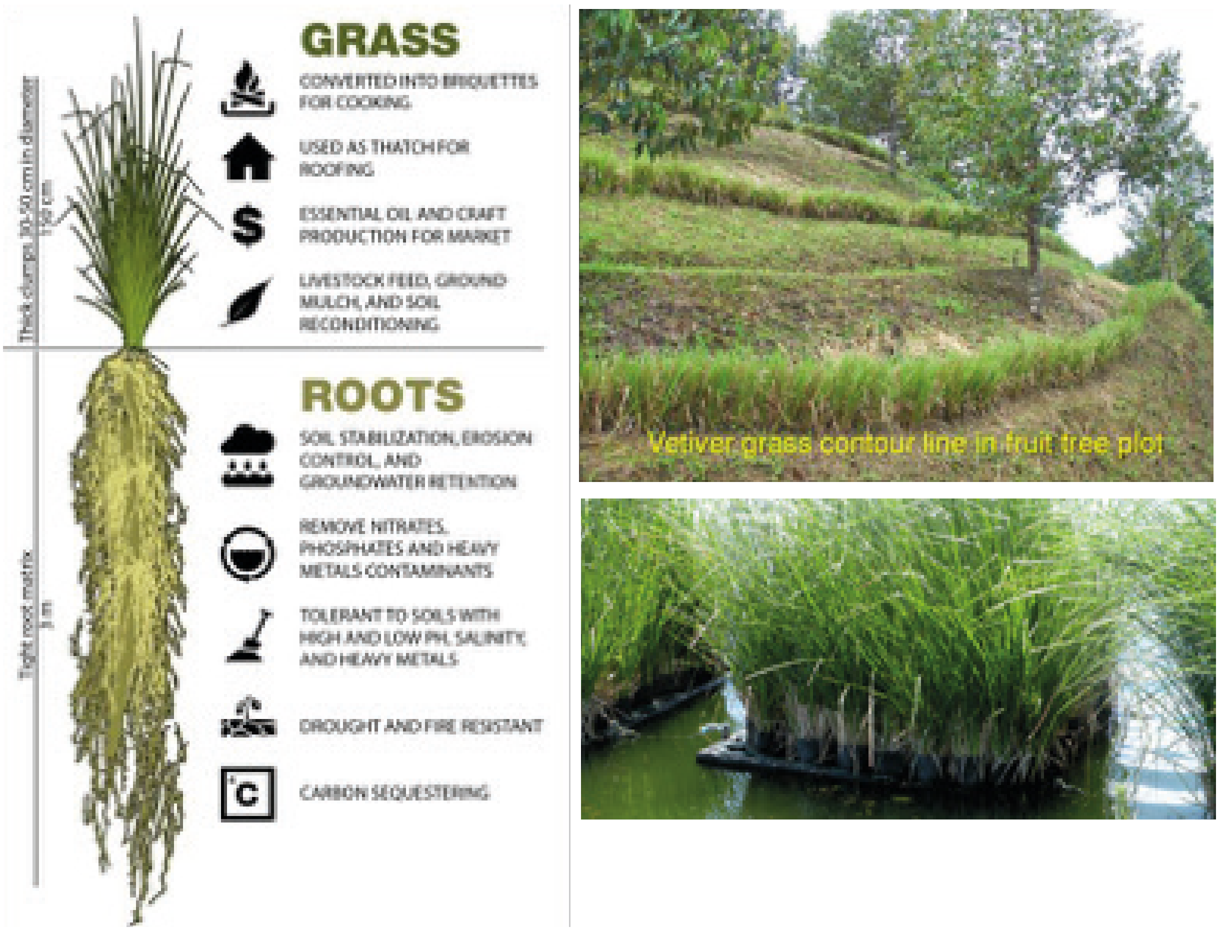
In addition, Vetiver grass leaves and roots can be used:

- **As a source** of feed for livestock and wildlife
- **For pest control** (intercropping, bio-pesticide)
- **For handicraft** (baskets, hats)
- **In building construction** (bricks, roofing)
- **For water purification** and medicinal purposes
- **As an ingredient** for cosmetics

Some special attributes of Vetiver grass include;

- **A deep, penetrating and extensive root** system that binds the soil, and reinforces the structure.
- **Erect and stiff stems** and leaves forming a dense hedge that is very effective in reducing the erosive power of strong water flows
- **Vetiver is tolerant** to a wide range of climatic conditions, temperature ranges from –minus 14 degrees Centigrade to 55 degrees Centigrade
- **Vetiver is tolerant** to drought, saline, sodic and acidic soil conditions
- **Vetiver survives** under prolonged and complete submergence and it resumes growth after the water recedes
- **Vetiver regenerates quickly** after a fire

View this video (7:40mins) on how the Vertiver System can be used to stop erosion in high rainfall tropical location whilst the collage illustrates some of these points. It also stresses the beneficial effects it has on soil quality and the improvement of water quality. It is an exceptional plant for the use of bio-mitigation and bio-remediation and will play an important role in large scale ecosystems restoration as we will see more and more large scale restoration projects during the coming decades.



Collage of Vetiver Grass System [*https://www.vetivergrassuk.com/*](https://www.vetivergrassuk.com/)
Floating raft for waste water treatment

4.10. Biochar

One of the techniques that scores highest for its greenhouse gas abatement rate is the application of biochar (World Bank, 2012). Biochar can be obtained on farms from the carbonization of biomass through pyrolysis or gasification. The International Biochar Initiative maintains that – applied correctly – "the carbon in biochar resists degradation and can hold carbon in soils for hundreds to thousands of years". It needs to be applied in combination with organic nutrients (e.g. liquid compost) to have a positive effect on yields. "Biochar and bio-energy co-production can help combat global climate change by displacing fossil fuel used and by sequestering carbon in stable carbon pools" (Biochar International, 2015). There is increasing evidence that indigenous cultures of Amazonia, Asia and possibly even Europe practice the burial of organically activated biochar (see Terra Preta).

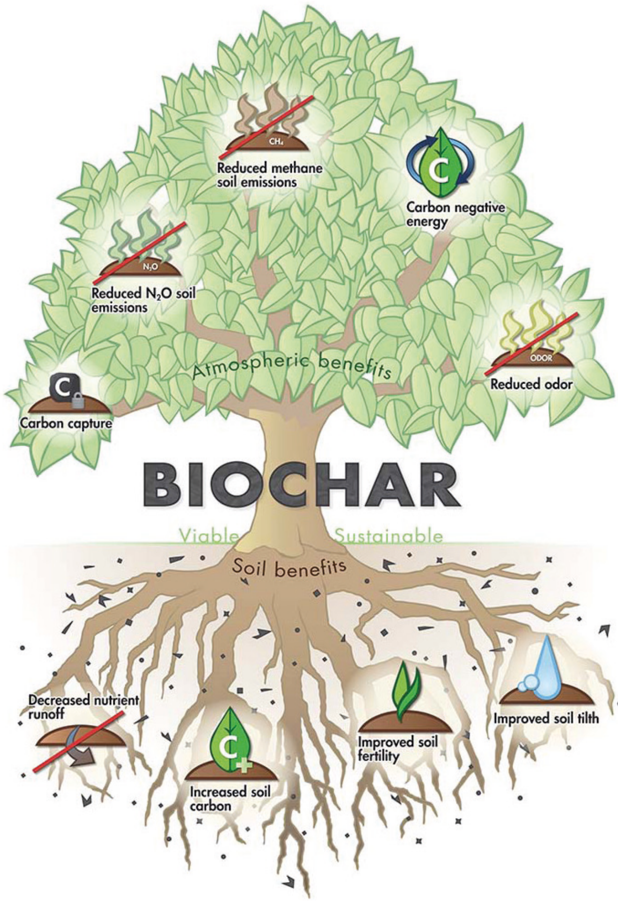
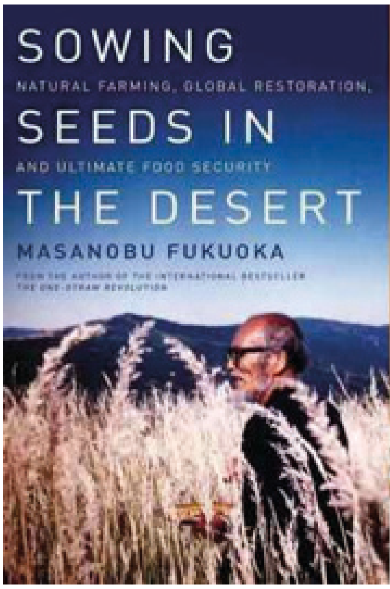


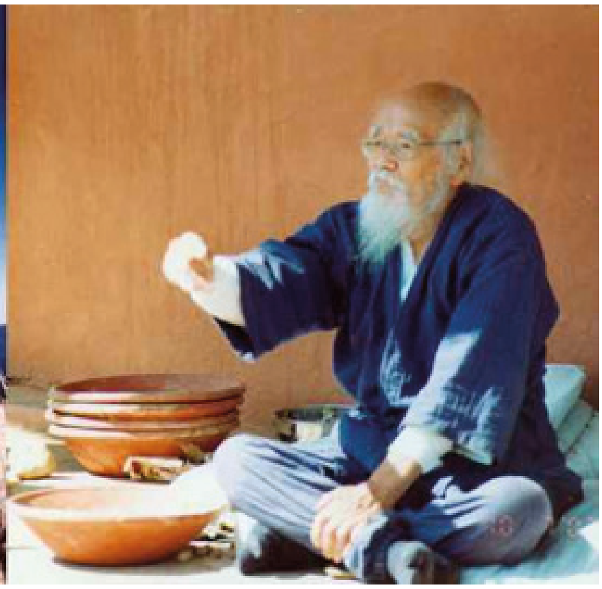
Figure 4.10: Figure 4.10: The benefits of Biochar (source)

4.11. Seedballs

The wide ranging use of Seedballs was rediscovered by the Japanese Natural Farming pioneer Masanobu Fukuoka as he sought solutions to green the deserts. Historical attempts to seed vast areas via aerial methods proved ineffective for various reasons, primarily due insects and rodents eating the seeds, which in turn caused a proliferation of rodents. Fukuoka analysed these approaches and enhanced an ancient technique to coat the seeds within a clay ball with compost, which rodents would not eat. This method has been successfully tested by Fukuoka and other researchers, and written about in the book, "Sowing Seeds in the Desert". The seedball methodology has been successfully replicated and enhanced by several development agencies around the world.

The construction of seedballs of between 10 to 80 mm proved successful when made with a 50/50 mixture of clay and compost and watered with nutrient rich worm tea and/or effective micro-organisms. More recently, bits of biochar and mycelium have also been added to the seedball mix. The dispersal of these seedballs, usually by hand and sometimes aerially, would see them roll into suitable niches where they would wait until the perfect conditions manifested, usually the first rains. Thereafter, the first rains would moisten the seedball, allowing water infiltration, thereby sparking the seed(s) to grow, and burst forth in a dissolving seedball making a nest of compost, biochar and mycelium, the perfect ingredients to flourish in nature.





A development agency which is successfully using seedballs, is [Seedballs Kenya](), whose experience is documented in [this video]() (5mins).

In recent years, drone technology has been developed using paintball gun methods to drill the seedballs precisely where planned, for example, along swales, a food forest plan, etc. The efficiency and cost effectiveness of drones have the potential to cover vast areas with seedballs as part of massive reforestation programmes.

However, despite this potential, one also needs to ensure that such impressive technology is used for good intentions and not to replace destroyed forests with plantations, but rather, to plant guilds of trees that can grow symbiotically into a forest, such as shown in [this video]() (2 mins) from Dronecoria: Open Source Restoration.

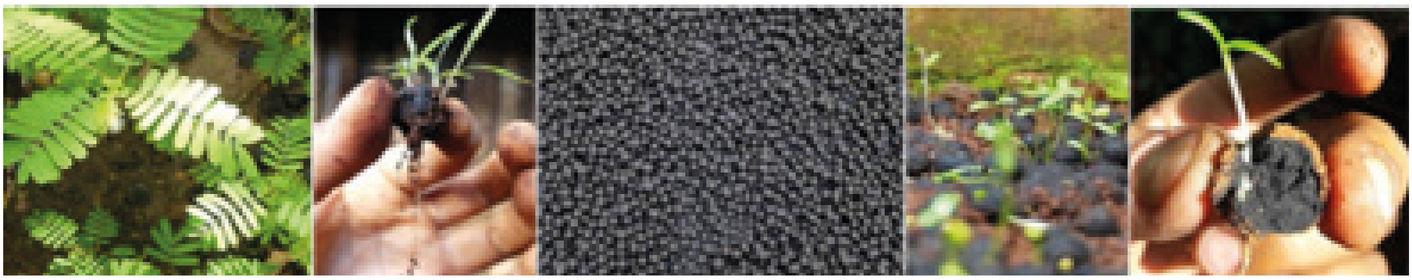


Plate 4.12: Seedballs, source, [Seedballs Kenya]()

5. Sustainable Food Systems

Why local foods?

As expert soil scientists such as Dr Elaine Ingham and Dr Christine Jones point out, we need no soil amendments to ensure healthy plants; all we need to do as gardeners and farmers is to work with nature to ensure that we have a healthy soil microbiome that releases nutrients from parent material in the soil and healthy ecosystems that redistribute nutrients. But we also need to ensure that those nutrients are returned to the soil for various reasons:

- **Waste from one organism is food** for another and completing the nutrient cycles locally ensures that we do not degrade our ecosystems. The local food webs mentioned above, therefore, are crucial to the overall health of an ecosystem, so we have to maintain the above ground, grazing food web that transfers energy and nutrients upwards in the system, as well as the (partially) below-ground detrital food web that breaks down and returns nutrients to the system. In the grazing food web, photosynthesising plants are the primary producers that are consumed by herbivores and so on up to the top predators. The detrital food chain takes dead organic matter and reduces it to its nutrient parts through scavengers (such as hyenas and vultures etc.), shredders (larger arthropods), digesters (smaller arthropods, worms, bacteria and fungi). We can clearly see that loss of biodiversity is a major threat to the sustainability of these food webs and the loss of nutrients from waste is a threat to biodiversity.

- **Microbiologists and some nutritionists** also suspect that there is a relationship between the local soil microbiota and the gut microbiomes of local people and that a predisposition towards local varieties of food, local cuisines and microbiome health is passed down epigenetically from generation to generation.

- **Global trade in food,** and our present system of water-carrier disposal of excrement, breaks these nutrient cycles, washes nutrients out to sea instead of returning them to the soil.

Our own gut microbiome is part of this nutrient cycle (**Figure 5.1**). Imports of food break with our part in the cycle, and with the local microbiome. The focus of our global economy on agriculture for export is equally disruptive of our local nutrient cycle, because it exports both nutrients and water.

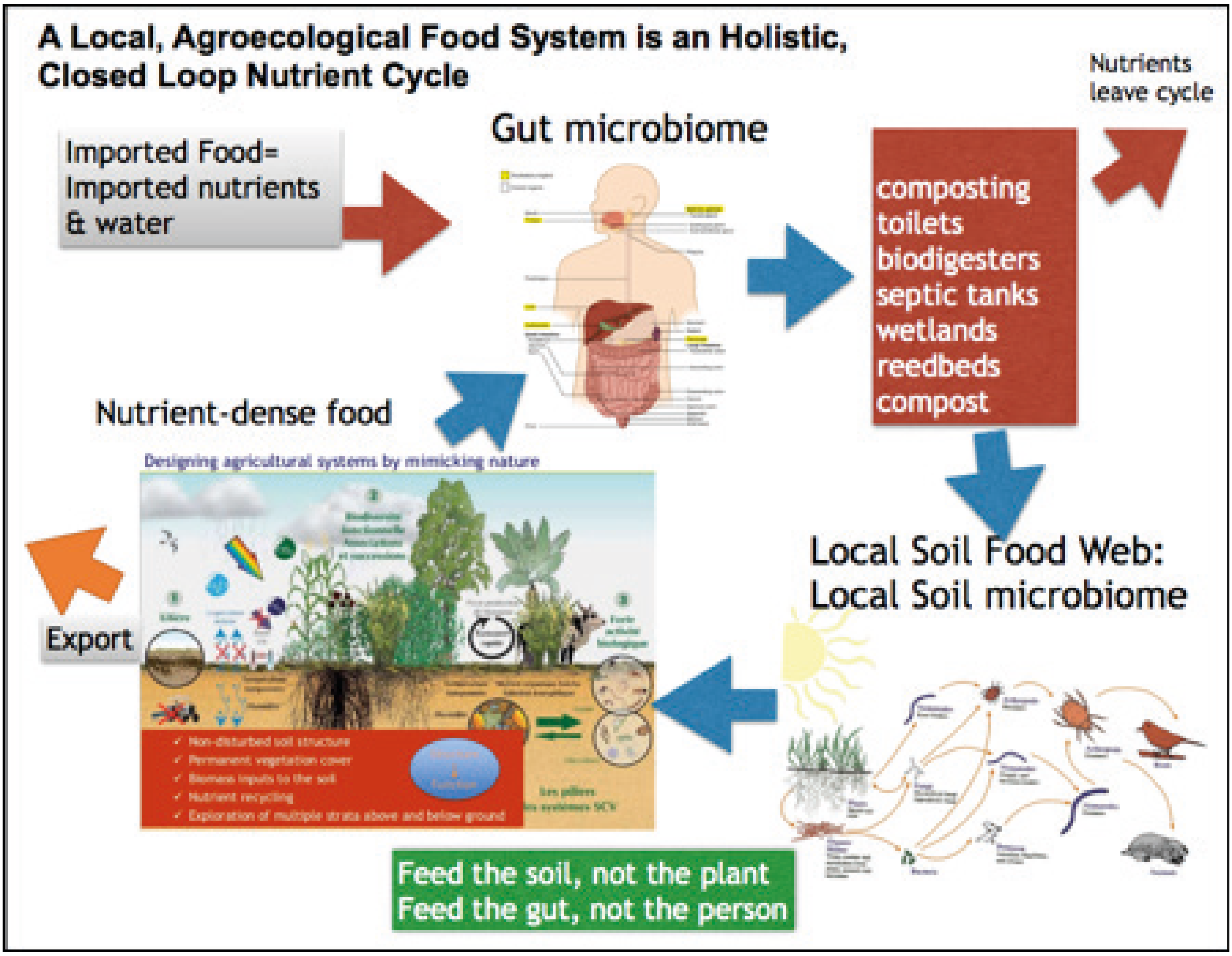


Figure 5.1: Closed loop nutrient cycle

Besides the obvious benefits to a rural economy and revitalised community from a transition to locally produced foods, fresh and nutrient dense, sold at farmers markets, this transition is an absolute imperative for ecosystem health, the functional cycles and human well-being. We cannot afford to destroy the Earth microbiome that has been assuring the continuance of life on this planet for most of its 4.5 billion years.

5.1. Research into Sustainable Food Systems

This section explores the growing field of Sustainable Food Systems (SFS), particularly since, according to the IPCC 2019 report, the global food system has been estimated to be responsible for between 21-37% of total net anthropogenic GHG emissions. It stands to reason that by embedding sustainability within the global food system, a significant impact can be made to mitigate climate change. However, the resources that drive the modernity of the global food system, has created a huge complexity gap with traditional food systems, hence the need for research into SFS in order to bridge this divide.

Besides mitigating climate change, an SFS should also provide healthy food which has a positive impact upon related environmental, economic and social factors. A SFS starts with sustainable agricultural practices; leading to more sustainable and equitable food distribution; an emphasis on local sustainable traditional diets; a reduction of food waste throughout the process; and, by promoting the local circular economy in harnessing local capitals, such as, natural resources, finances, farmers, value-adding processes, labour and traditional social capital. Given these basic requirements of SFS, it can be seen that SFS are central to all 17 Sustainable Development Goals. To this end, it was stated by FAO (2018) in "Transforming food and agriculture to achieve the SDGs", "that food and agriculture, the prime connection between people and the planet, can help achieve multiple SDGs". Furthermore, in this connection, the Stockholm Resilience Centre in 2016 reported a new way of viewing the SDGs and how they are all linked to food by considering economies and societies like embedded parts of the biosphere, as shown in **Figure 5.2**. More specifically, they stated that, "This model represents a new way of viewing the Sustainable Development Goals and how they are all linked to food. It calls for a shift away from the current sectorial approach where social, economic, and ecological development are seen as separate parts. Instead we must transition toward a logic where the economy serves society so that it evolves within the safe operating space of the planet".

Figure 5.2: How food connects all the SDGs, Stockholm Resilience Centre

5.2. Certification Systems

It seems like a travesty of justice that in order for sustainable practices on agricultural enterprises to be accepted, they need to be formally validated and certified organic, whereas industrial agricultural enterprises can simply conduct business as usual. Although it is discerning consumers that need to be satisfied about the authenticity of organic produce, in time, the same consumers will hopefully grow in numbers and become more outspoken to demand that harmful industrial agricultural enterprises should have strict permits to operate, whilst organic agriculture becomes the new business as usual model. Meanwhile, the current organic producer standards do set a reasonable benchmark for sustainable agriculture in order to compare against industrial agriculture. Some of the common certification systems of sustainable agriculture are explored below:

Organic Certification by IFOAM:

The existence of agreed standards based on national systems brought together by IFOAM has allowed international trading of organic products to take place with a good level of assurance that products are really organic. The market for organic produce is growing in many countries. There is pressure from governments and large agricultural corporations to reduce standards, including the percentage of organic content in products, especially when demand exceeds supply. IFOAM, the Soil Association in the UK, and the Rodale Institute continue to be the guardians of high levels of standards. Organic certification is also available for groups of small-scale farmers wherein their formally constituted association, co-operative or even an organic packshed, is certified organic, which in turn, provides a guarantee that the collective of small scale producers are organic. This is called a participatory guarantee system (PSG) and significantly lowers the cost of organic certification for small scale farmers.

Biodynamic Certification:

Biodynamic Agriculture emphasises balancing the holistic development and interrelationship of the soil, plants, animals as a closed, self-nourishing system. Biodynamics has its own certification system, which covers all the requirements for organic farming plus certain additions, including a longer conversion period for the land to be prepared for Biodynamic Certification. Demeter International is the largest certification organisation for biodynamic agriculture and is also one of three predominant organic certifiers.

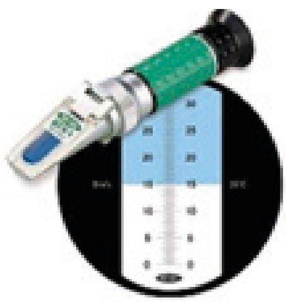
Fair Trade:

This movement seeks to promote greater equity in international trading partnerships through dialogue, transparency, and respect. It promotes sustainable development by offering better trading conditions to, and securing the rights of, marginalized producers and workers in developing countries. (Source: Fairtrade, Wikipedia).

The Fairtrade Standards combine a range of economic, environmental and social criteria that are independently audited as part of Fairtrade certification. These criteria reflect Fairtrade's goal to promote sustainable production and decent livelihoods. When you buy Fairtrade, you help to ensure these factors are not casually written off as 'externalities' or treated as costs that farmers and workers should bear alone. (Source: Fairtrade).

5.3. Nutrient rich plant crops

The agricultural sector has long been using Brix levels as an indicator of sugars / sucrose, or sap density, content for wine, sugar, carbonated beverage, fruit juice, maple syrup and honey products. A refractometer is a widely used small instrument that measures Brix, defined as the amount of refraction (or bend) in a beam of light that passes through the plant sap. Although the plant sap contains both carbohydrate chemicals / sugars and mineral ions, it is primarily the sugars in the sap that causes refraction, mainly because the primary activity of plants is photosynthesis, and also, due to the larger size of the sugars compared to the mineral ions within a molecule. Each plant has a unique sap signature, and consequently, a unique range of Brix levels from poor to excellent readings, as indicated in the chart in **Table 5.4**.



Graeme Sait, an author / educator, and founder of Nutrition Farming®, has recognized how Brix can measure the very important link between soil health and plant vitality. Herein, poor fertility and nutrition weakens the immune system of plants, and thereby, the natural, microbe-based defence mechanisms in the soil becomes compromised, which in turn, attracts opportunistic pests that eradicate these low vitality crops. Sait has for many years crusaded that retailers should pay for farmers' produce not by weight, but by Brix levels, so that consumers can eat high value for money, nutritional fruit and vegetables, which ought to shift the emphasis towards regenerative agricultural practices. In this short video (3 mins), Sait highlights how "chemical (industrial farming)" is driven by fear of failure and a fascination with short-term unsustainable solutions, as opposed to "biological farming" which is driven by love as farmers take a long-term view and care of their environment by being both food growers and land stewards.

Sait has also blogged about "The Beauty of Brix – Ten Things You Need To Know", which hails the refractometer as a "hardy, inexpensive, user-friendly tool that will predict your crop's pest pressure, yield potential, quality, shelf-life, calcium status and weed problems", as well as, "it will even detect boron deficiency, foliar spray suitability and the likelihood of frost damage".

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Refractive Index of Crop Juices -- Calibrated In % Sucrose Or °Brix

	Poor	Average	Good	Excellent
FRUITS				
Apples	6	10	14	18
Avocados	4	6	8	10
Bananas	8	10	12	14
Blueberries	10	14	16	20
Cantaloupe	8	12	14	16
Casaba	8	10	12	14
Cherries	6	8	14	16
Coconut	8	10	12	14
Grapes	8	12	16	20
Grapefruit	6	10	14	18
Honeydew	8	10	12	14
Kumquat	4	6	8	10
Lemons	4	6	8	12
Limes	4	6	10	12
Mangos	4	6	10	14
Oranges	6	10	16	20
Papayas	6	10	18	22
Peaches	6	10	14	18
Pears	6	10	12	14
Pineapple	12	14	20	22
Raisins	60	70	75	80
Raspberries	6	8	12	14
Strawberries	6	10	14	16
Tomatoes	4	6	8	12
Watermelons	8	12	14	16
GRASSES				
Alfalfa	4	8	16	22
Grains	6	10	14	18
Sorghum	6	10	22	30

	Poor	Average	Good	Excellent
VEGETABLES				
Asparagus	2	4	6	8
Beets	6	8	10	12
Bell Peppers	4	6	8	12
Broccoli	6	8	10	12
Cabbage	6	8	10	12
Carrots	4	6	12	18
Cauliflower	4	6	8	10
Celery	4	6	10	12
Corn Stalks	4	8	14	20
Corn (Young)	6	10	18	24
Cow Peas	4	6	10	12
Cucumbers	4	6	8	12
Endives	4	6	8	10
English Peas	8	10	12	14
Escarole	4	6	8	10
Field Peas	4	6	10	12
Green Beans	4	6	8	10
Hot Peppers	4	6	8	10
Kohlrabi	6	8	10	12
Lettuce	4	6	8	10
Onions	4	6	8	10
Parsley	4	6	8	10
Peanuts	4	6	8	10
Potatoes	3	5	7	8
Potatoes, Sweet	6	8	10	14
Romaine	4	6	8	10
Rutabagas	4	6	10	12
Squash	6	8	12	14
Sweet Corn	6	10	18	24
Turnips	4	6	8	10

Within a given species of plant, the crop with the higher refractive index will have a higher sugar content, higher mineral content, higher protein content and a greater specific gravity or density. This adds up to a sweeter tasting, more minerally nutritious food with lower nitrate and water content, lower freezing point, and better storage attributes.

This Chart was originally developed by Dr. Carey Reams.

BIONUTRIENT Food Association

Bionutrient Food Association/Real Food Campaign | 411 Sheldon Rd. Barre, MA 01005 | info@bionutrient.org | Tel. +1 (978) 355-1100

Table 5.4: Refractive Brix indices of crop juices

5.4. Community Supported Agriculture

In a typical Community Supported Agriculture (CSA) system a group of people form a cooperative, which grows food in a sustainable way, with the group taking responsibility for organising and paying the costs of the food production. It is sometimes called subscription farming. The CSA needs to obtain the use of land, the services of a farmer or farmers, working capital for machinery, storage and distribution, administration and also voluntary help on the land at peak labour times provided by the CSA members. A CSA's focus is usually on a system of weekly delivery or pick-up of vegetables and fruit, as shown in **Plate 5.5**.

Plate 5.5: Typical CSA veggie-box

Payment of each person's or family's subscription will probably be at the beginning of the year to enable supplies to be purchased and in monthly instalments through the season. Within this basic structure, the main variations will be in how much the subscriber group puts in voluntary work versus opting to pay for all the labour.

The first CSA projects began during the early 1970s in Germany. They were connected with communities that had grown out of the anthroposophical movement created by Rudolf Steiner in the twenties and thirties. In some ways they can be seen to predate the ecovillage movement as they had a clear intention to combine all necessities of life (food production, shelter, education, job creation, etc.) within them, but were not communes and so needed their own systems for distribution and finance (more on biodynamic CSA).

The idea was taken up in the US during the eighties with perhaps 60 CSAs in existence by 1990. By 1997 there were more than 1,000 in the US involving some 100,000 households, with many more in other parts of the world. This growth has also been accompanied by the development of many variations on the basic theme. Local Harvest in the USA links CSA schemes to consumers who would like to join.

One radical variation has the supporters divide up the costs of farming according to their ability to pay and then allows them to take the produce they need according to their family size. This represents the end of the spectrum requiring the most trust and community. At the other end of the scale, the many "box schemes", which have come into existence supplying a weekly box of vegetables to order, can be seen as an urban development of CSA principles without the direct connection between consumers and land. This link shows a short video (11min) by the Soil Association introducing one example of a small CSA scheme in Devon, England.

5.5. Urban Agriculture

Across the world, citizens of towns and cities are coming together to grow food and build community to counteract socio-economic degradation and to ensure food security. Permaculture design principles can be used in any location and play a crucial role in establishing community resilience and energy descent. This form of urban agriculture is taking many forms and shapes; from private and community owned options; and across, balcony spaces, rooftops, allotments, sidewalks, common areas, community gardens, etc.

Small gardens, balcony spaces and rooftop gardens often make use of movable wicking-type planter boxes, with a compost worm tower if space permits, which requires minimal irrigation maintenance. The inside of the planter boxes / barrels should first be waterproofed with a plastic membrane and then lined with a geotextile membrane (similar to a thin blanket), which creates the wicking action that draws water upwards to the plant roots – a closed loop system - as shown in the sketch in **Figure 5.6a**. An example of a worm compost tower within a planter barrel and a vertical planter is shown in **Figure 5.6b**.

Figure 5.6b: Wicking planter bucket with worm compost tower (Source: Urban Green Space)

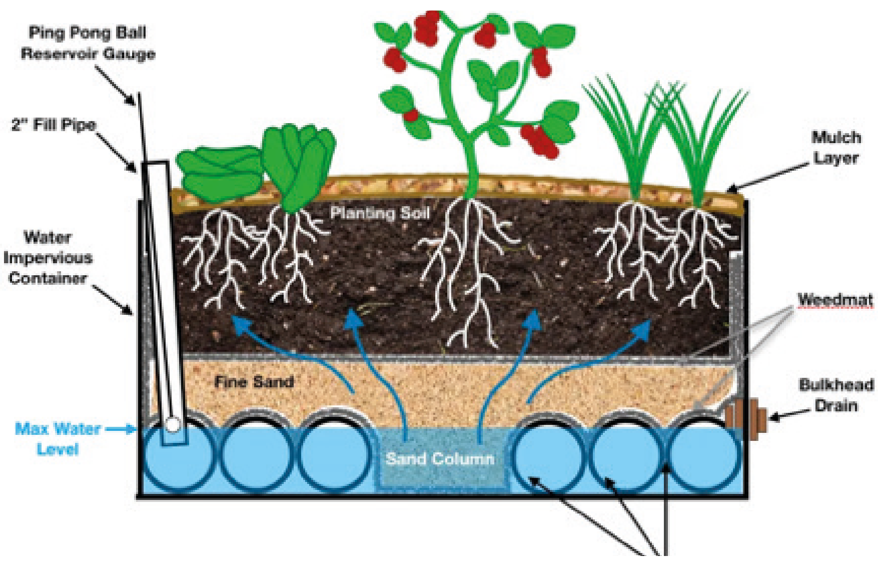


Figure 5.6a: Wicking planter box

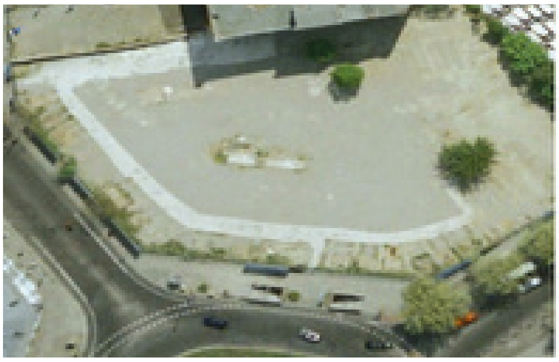
Allotment gardens are found across Europe under various names and each have an interesting history depending upon the urban circumstances at the time. The underlying land of an allotment or community garden is usually owned by the municipality or local parish, which is zoned for agriculture, is leased individually or to a collective. The basic difference between an allotment and a community garden, is that allotments are small land parcels which are tended individually (anywhere from 12 to 400m2), whilst community gardens are tended collectively by a group of people or an association / entity. The legalities of privately owned or leased spaces are usually easier to manage than community managed spaces.

These urban agricultural spaces can transform the urban landscape by creating much needed green spaces, thereby providing a wonderful space for people to meet, socialise, exchange gardening tips, recycle organic waste to compost, etc. According to several independent studies, the yields of bio-intensive allotments and community gardens in urban areas have shown to be up to twice that of conventional farmland and contribute significantly to family's fresh fruit and vegetables. A collage of allotment and community gardening has been compiled to showcase these projects across the world.

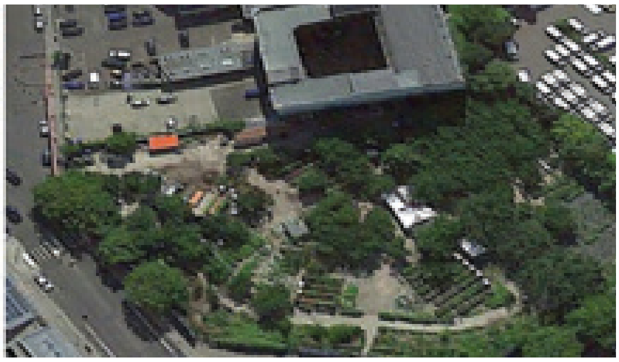
(1)

(2)

(3)



(4)



(5)

(6)

(7)

Collage of Allotments and Community Gardens: ***(1)*** *Midsomer Norton Community Allotments, UK;* ***(2)*** *Hale Road Allotments in Swavesey, UK;* ***(3), (4)*** *Prinzessinnengärten, Berlin;* ***(5), (6), (7) Source:*** *dailydetroit.com*

5.6. Farmers' Market

Farmers' Markets are a trading platform where farmers sell their produce directly to the public. This direct selling method avoids additional costs associated with middle-men, cold chain logistics, packaging, transport, storage, double handling, etc. Farmers can therefore reduce prices and still have relatively higher profit margins, whilst providing cost effective fresh quality seasonal products for consumers. These Farmers' Markets are found worldwide where farmers and consumers interact and exchange quality value for money. The worldwide interest and growth of the organic produce sector has seen a huge parallel growth in Farmers' Markets that trade in organic and related value-adding products. Consumers have also become more interested in how their fresh vegetables and fruit are grown, and Farmers' Markets provide this platform. This social interaction between farmers and consumers strengthens the social capital of a community and builds trust. It is this trust in farmers' cultivation methods and quality of produce within a community that helps to avoid costs associated with organic certification.

The human traffic at Farmers' Markets are much valued by neighbouring businesses, thereby creating symbiotic relationships which are mutually beneficial. Many old town and city centres built prior to the advent of the motor vehicle, provided trading spaces in the town centre or specific plazas / squares where stalls and small shops were accommodated for farmers and other traders. Nowadays, the unique purpose for many such plazas with their surrounding stalls and small shops has long been forgotten, and replaced by coffee-shops, bars, restaurants, etc. However, the hustle and bustle of Farmers'.

Markets are slowly rediscovering these former trading places within town centres as a new wave of urban regeneration takes over which endeavours to add value to the built environment by restoring spaces for the social capital to develop.

A good example of the important role of Farmers' Markets is made by EURACTIV's partner Sicilia Agricoltura, which reports that, "Farmers' Markets have spread across Italy in just a few years and they offer a great economic and social opportunity, precisely because they allow direct contact between producers and consumers", as shown in **Plate 5.7.** EURACTIV further reports that, "Short food supply chains are more than selling local products. Short food supply chains have a multidimensional role to play. They can help revitalise European farms by encouraging young people to work the land, but they also provide cheap and healthy food to consumers and attract tourists".

Plate 5.7: A farmer selling directly his product at the famous local market Ballaro in Palermo, Italy.

5.7. Slow Food Movement and Agri-Tourism

The Slow Food movement had a humble beginning in 1986 as a protest action against a global food player (McDonalds) in a popular tourist destination (Piazza di Spagna, Rome). Opposed to the "fast food" concept, the Slow Food protest instead preserved the local Italian cuisine of quality, taste and experience. This protest action soon grew into a worldwide movement which supports local- farmers, agri-business, small markets, restaurateurs, etc. An important principle of Slow Food is to reduce the "food miles" from "farm to fork", thereby reducing the ecological footprint of Slow Food. Although not strictly defined, the criteria for Slow Food is the sourcing of food within 30 miles or 50 kms from source but double this distance has also been deemed acceptable given specific geographical considerations. The Slow Food movement is therefore an important contributor to the local circular economy.

The Slow Food philosophy is based on a concept of food that is defined by three interconnected principles, as described in the Slow Food Manifesto below.

Good, Clean and Fair: the Slow Food Manifesto for Quality

Slow Food®

The food production and consumption systems most common today are harmful to the earth, to its ecosystems and to the peoples that inhabit it.

Taste, biodiversity, the health of humans and animals, well-being and nature are coming under continuous attack. This jeopardizes the very urge to eat and produce food as gastronomes and exercise the right to pleasure without harming the existence of others or the environmental equilibria of the planet we live on.

If, as the farmer poet Wendell Berry says, "eating is an agricultural act", it follows that producing food must be considered a "gastronomic act".

The consumer orients the market and production with his or her choices and, growing aware of these processes, he or she assumes a new role. Consumption becomes part of the productive act and the consumer thus becomes a co-producer.

The producer plays a key role in this process, working to achieve quality, making his or her experience available and welcoming the knowledge and knowhow of others.

The effort must be a common one and must be made in the same aware, shared and interdisciplinary spirit as the science of gastronomy.

Each of us is called upon to practice and disseminate a new, more precise and, at the same time, broader concept of food quality based on three basic, interconnected prerequisites. Quality food must be:

1) Good. A food's flavour and aroma, recognizable to educated, well-trained senses, is the fruit of the competence of the producer and of choice of raw materials and production methods, which should in no way alter its naturalness.

2) Clean. The environment has to be respected and sustainable practices of farming, animal husbandry, processing, marketing and consumption should be taken into serious consideration. Every stage in the agro-industrial production chain, consumption included, should protect ecosystems and biodiversity, safeguarding the health of the consumer and the producer.

3) Fair. Social justice should be pursued through the creation of conditions of labour respectful of man and his rights and capable of generating adequate rewards; through the pursuit of balanced global economies; through the practice of sympathy and solidarity; through respect for cultural diversities and traditions.

Good, Clean and **Fair** quality is a pledge for a better future. Good, Clean and Fair quality is an act of civilization and a tool to improve the food system as it is today. Everyone can contribute to Good, Clean and Fair quality through their choices and individual behaviour.

The consumer boom to experience the Slow Food gastronomy, has also promoted the tourist boom for agri-tourism, or "farm-stay" experiences, which are known under various names in many countries around the world, for example, Agriturismo Italy. To acquire planning approval for an agriturismo project in Italy, there are strict planning and operational requirements which uphold the specific traditional characteristics of a region, such as, serving a significant portion of local food grown and/or produced on site, or from the autonomous region, anywhere up to 60%, depending on the regional regulations.

Like the Slow Food movement, people have become more interested in how their food is produced and want to meet farmers and agri-value adding producers in order to talk to them about what goes into food production. This has also led to the rediscovery of traditional artisanal trades in food production and rural craftwork, in other words, a rekindling of cultural landscapes. Agri-Tourism offers various activities, such as:

· **Farmgate-to-consumer sales** (eg. farmstalls, veggie-box pick-ups, seed exchanges, seedlings sales).

· **Education and cultural awareness** (eg. school visits to a farm, animal touch farms, various training courses and internships (sustainable agriculture, cooking classes, craftwork, hospitality training), and WWOOFing experiences).

· **Hospitality** (eg. overnight farm stays, AirBnB).

· **Recreation** (eg. hunting, horseback treks, sporting activities, pilgrimage stopovers).

· **Entertainment** (eg. Slow Food restaurant, seasonal events, harvest festivals and custom events).

Farmers use the above activities to attract tourism traffic to their farm, thereby establishing fully fledged agri-tourism facilities, which are often promoted by the local municipality or local tourism agency. In turn, these agri-tourism facilities, as well as, certified organic farms, ecovillages, local farmers' markets, slow food restaurants, etc., all contribute towards creating the essential stepping stones towards the next level of sustainable regional development, as in a BioDistrict.

5.8. BioDistrict Approach to Sustainable Food Systems – The Italian Experience

As background, most local organic market chains have start-up challenges in moving from small niche markets to supplying large-scale markets with volume, and consequently, mainstream wholesalers and retailers have challenges in securing and promoting organic produce. These challenges exist primarily due to the grip of industrial based agriculture and its associated agro-business value chains.

Despite these challenges, there have been some innovative pioneering initiatives in Italy to establish BioDistricts, based upon watersheds, valleys, etc., which strongly supports small scale organic producers. This pioneering initiative led to the establishment in 2014 of the International Network of Eco-Regions (IN.N.E.R), which is designed to foster cooperation between Italian BioDistricts and similar initiatives in Europe and other continents. IN.N.E.R has defined a BioDistrict, or EcoRegion, as, "A territory naturally devoted to organic, where farmers, citizens, public authorities, realize an agreement aimed at the sustainable management of local resources, based on the principles of organic farming and agroecology".
The forerunners of the BioDistrict model, the Cilento area in Italy, have established this model around three main dimensions (Source: Healthy Growth):

The social dimension. It is about, more specifically, the development of social cohesion in support of sustainable and inclusive territorial development strategies; the improvement of social aggregation and cultural exchanges; the centrality of farmer's role; the revitalization of rural areas; the generation of new job opportunities, for vulnerable groups too, through social farming; and, the protection of farmer's and consumer's health.

The economic dimension. It focuses, in particular, on the economic benefits that organic farmers, tourist, cultural, catering enterprises can draw from the bio-district initiative; the reduction of organic certification costs which represent a significant financial burden for small farmers; the creation of new economic activities in the area; the promotion through territorial marketing tools (like AIAB Bio-Distretto® label); the aggregation of the organic supply; and, the access to alternative market channels (e.g. green public procurement and short supply chain initiatives).

The environmental dimension. It entails the protection and increase of biodiversity (through the cultivation of local seeds and ancient varieties); the protection of natural resources, especially of underground water sources; the improvement of soil fertility, alleviation of the desertification risk as well as of the greenhouse effect; landscape conservation; and, maintenance.

The advantages of the BioDistrict model is that the organic farming movement is allowed to grow and restore traditional cultural landscapes, one district at a time, uncontaminated from the industrial agro-business model. In time, as the boundaries of BioDistricts becomes blurred, a larger BioRegional model emerges, with even larger positive environmental impact.

5.9. BioRegional Approach to Sustainable Food Systems – The Cuban Experience

In certain parts of the world where communities have been challenged to feed themselves, there are some magnificent examples of urban agriculture and community gardening saving the citizens from starvation. In Cuba, shortly after the break-up of the Soviet Union (1990), famine threatened when their supply of artificial fertilisers and chemical pesticides dried up. Luckily, they were introduced to Permaculture and threw themselves whole-heartedly into food growing on every spare square metre of urban ground. As a result, Cuba has more urban agriculture than any other national territory and it is organic too (Source: Permaculture Magazine).

Cuba also introduced new legislation to boost the organic food security movement, namely: (1) to promote urban agriculture within a 5km radius around towns and cities; (2) to transfer parcels of rural land, from 1 to 5 ha, to small scale farmers; and, (3) to transfer ownership of large state agricultural co-operatives to local farmers. For participants particularly interested in this theme, the documentary, "The Power of Community: How Cuba Survived Peak Oil", illustrates the magnificent community spirit involved in the organic transformation of Cuban agriculture. This Cuban example is perhaps the first BioRegional, large-scale and island-wide, approach for a sustainable food system.

The concept of BioRegionalism is based on diversity and environmental stewardship of specific geographic regions, which Kirkpatrick Sale defines as, "It is any part of the earth's surface whose rough boundaries are determined by natural characteristics rather than human dictates, distinguishable from other areas by particular attributes of flora, fauna, water, climate, soils, and landforms, and by the human settlements and cultures those attributes have given rise to." (Source: Sale, K., "Dwellers in the Land: The Bioregional Vision", University of Georgia Press, 1991/2001). Furthermore, Sale's book review by University of Georgia Press, provides a fitting vision for a BioRegional Sustainable Food System as:

Figure 5.10: Cuban example of "Organoponico" food garden

"Imagine a world structured around ecological and cultural diversity, rather than national and political parameters. In response to present and impending ecological and economic crises, Kirkpatrick Sale offers a definitive introduction to the unique concept of bioregionalism, an alternative way of organizing society to create smaller scale, more ecologically sound, individually responsive communities with renewable economies and cultures. He emphasizes, among many other factors, the concept of regionalism through natural population division, settlement near and stewardship of watershed areas, and the importance of communal ownership of and responsibility for the land. Dwellers in the Land focuses on the realistic development of these bioregionally focused communities and the places where they are established to create a society that is both ecologically sustainable and satisfying to its inhabitants".

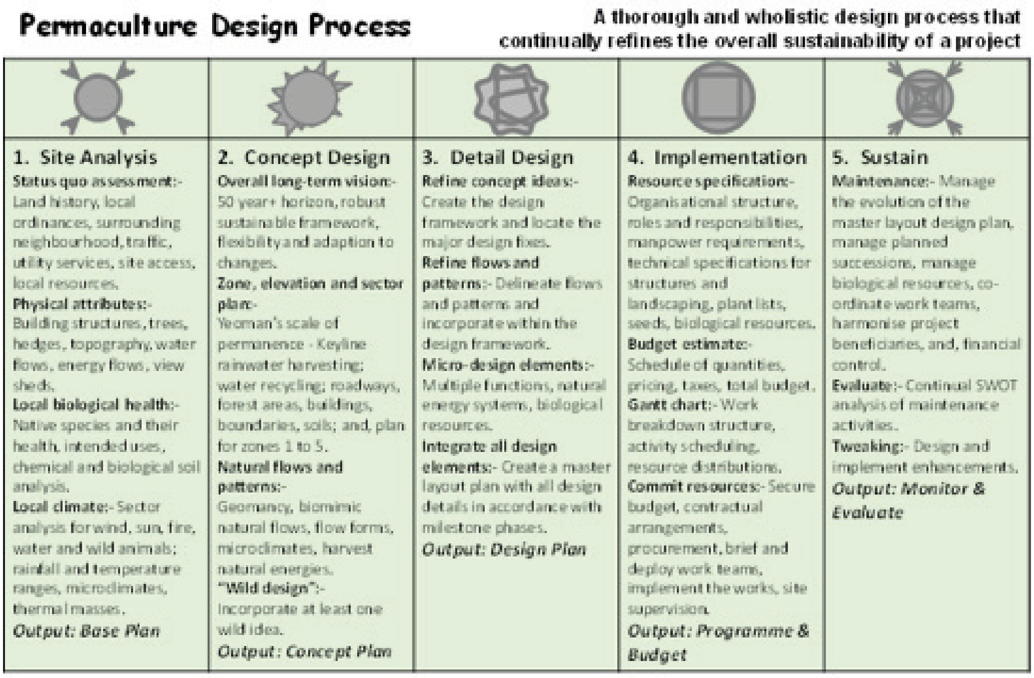
6.

Design Process and Case Studies

Permaculture Design Process

This Section initially unpacks a Permaculture design process, followed with a few collages of best practice farms, and finally, some further case study weblinks. This wealth of resources will provide students with ample information to digest well beyond the completion of this course.

To recap, of the sustainable agricultural systems, Permaculture lays out the intrinsic design principles; the Keyline System outlines the design sequence for these principles; and, Holistic Management provides the fundamental understanding of the whole integrated system. These three systems are now developed into a Permaculture design process as will be explained by subsequent slide inserts. Whilst there are many ways to undertake a Permaculture design process, the process explained has been developed along the lines of a project management stage design process. In the initial stages of a project, much research is undertaken in order to fully understand the nature of the project, but as this information is assembled and analysed, design solutions start to emanate, which in turn are further refined until a project design is reasonably completed and can be implemented from the detailed design and specifications. The Permaculture design process is explained in the slide below.

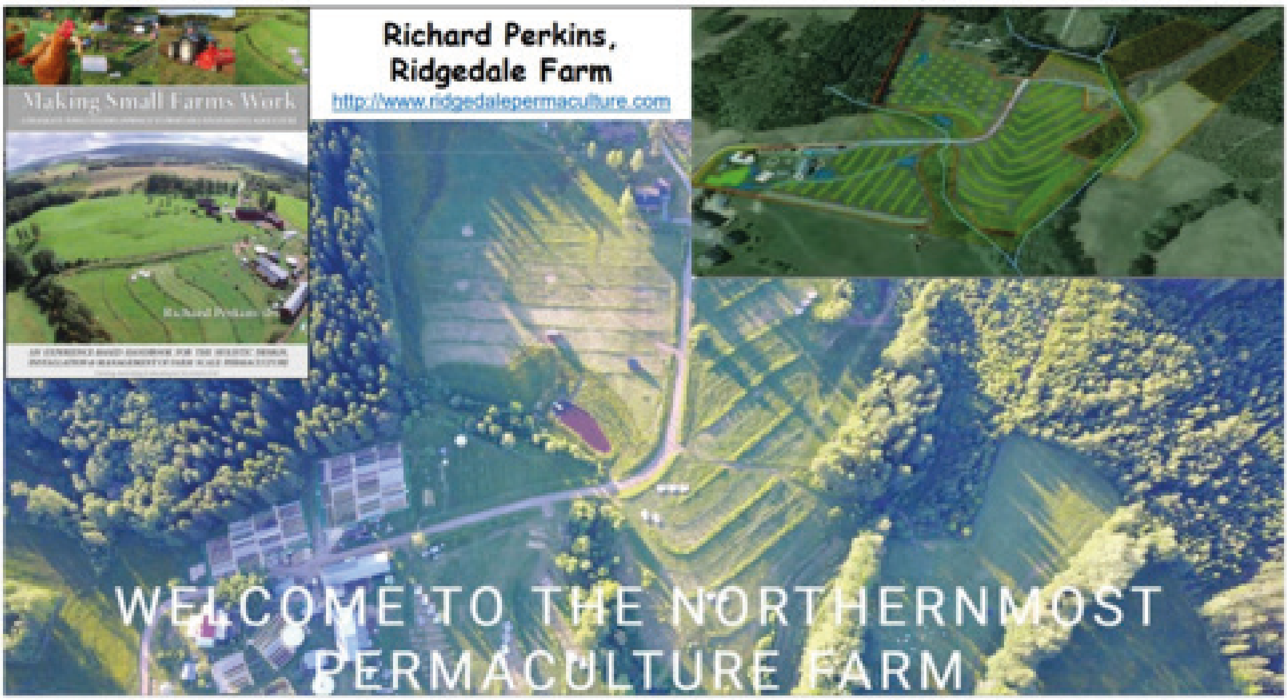

Permaculture Design Process

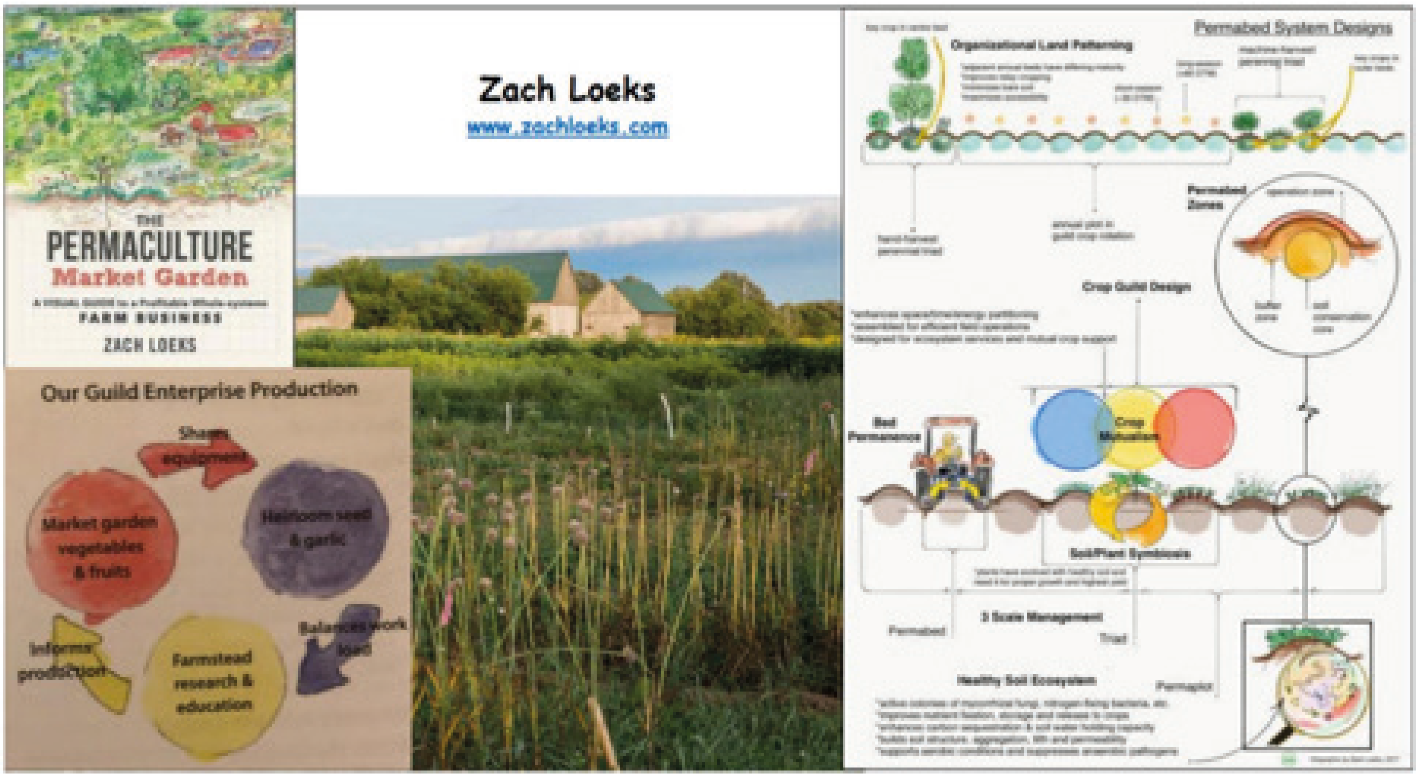
A thorough and wholistic design process that continually refines the overall sustainability of a project

1. Site Analysis	2. Concept Design	3. Detail Design	4. Implementation	5. Sustain
Status quo assessment:- Land history, local ordinances, surrounding neighbourhood, traffic, utility services, site access, local resources. **Physical attributes:-** Building structures, trees, hedges, topography, water flows, energy flows, view sheds. **Local biological health:-** Native species and their health, intended uses, chemical and biological soil analysis. **Local climate:-** Sector analysis for wind, sun, fire, water and wild animals; rainfall and temperature ranges, microclimates, thermal masses. ***Output: Base Plan***	**Overall long-term vision:-** 50 year+ horizon, robust sustainable framework, flexibility and adaption to changes. **Zone, elevation and sector plan:-** Yeoman's scale of permanence - Keyline rainwater harvesting; water recycling; roadways, forest areas, buildings, boundaries, soils; and, plan for zones 1 to 5. **Natural flows and patterns:-** Geomancy, biomimic natural flows, flow forms, microclimates, harvest natural energies. **"Wild design":-** Incorporate at least one wild idea. ***Output: Concept Plan***	**Refine concept ideas:-** Create the design framework and locate the major design fixes. **Refine flows and patterns:-** Delineate flows and patterns and incorporate within the design framework. **Micro-design elements:-** Multiple functions, natural energy systems, biological resources. **Integrate all design elements:-** Create a master layout plan with all design details in accordance with milestone phases. ***Output: Design Plan***	**Resource specification:-** Organisational structure, roles and responsibilities, manpower requirements, technical specifications for structures and landscaping, plant lists, seeds, biological resources. **Budget estimate:-** Schedule of quantities, pricing, taxes, total budget. **Gantt chart:-** Work breakdown structure, activity scheduling, resource distributions. **Commit resources:-** Secure budget, contractual arrangements, procurement, brief and deploy work teams, implement the works, site supervision. ***Output: Programme & Budget***	**Maintenance:-** Manage the evolution of the master layout design plan, manage planned successions, manage biological resources, co-ordinate work teams, harmonise project beneficiaries, and, financial control. **Evaluate:-** Continual SWOT analysis of maintenance activities. **Tweaking:-** Design and implement enhancements. ***Output: Monitor & Evaluate***

6.1. Case Study Collages

Case Study Collages have been compiled for the following projects / farms:
Joel Salatin, Polyface Farms, Richard Perkins, Ridgedale Farm,
Zach Loeks, Sepp Holzer, Krameterhof

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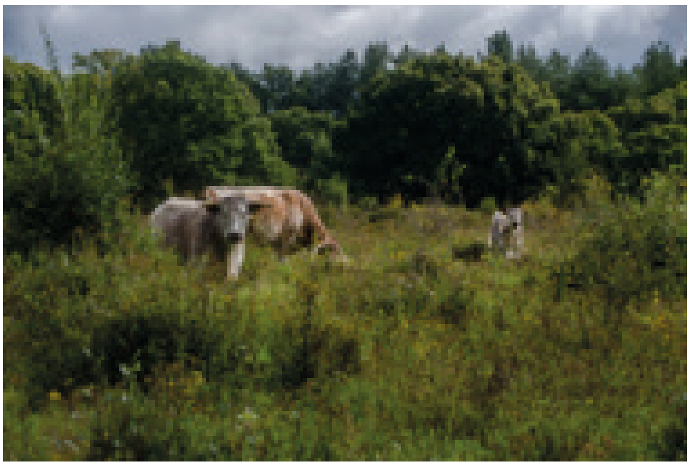
Organizational Land Patterning
Crop Guild Design
Crop Mutualism
Bed Permanence
Soil/Plant Symbiosis
3 Scale Management
Permabed
Triad
Permaplot
Healthy Soil Ecosystem

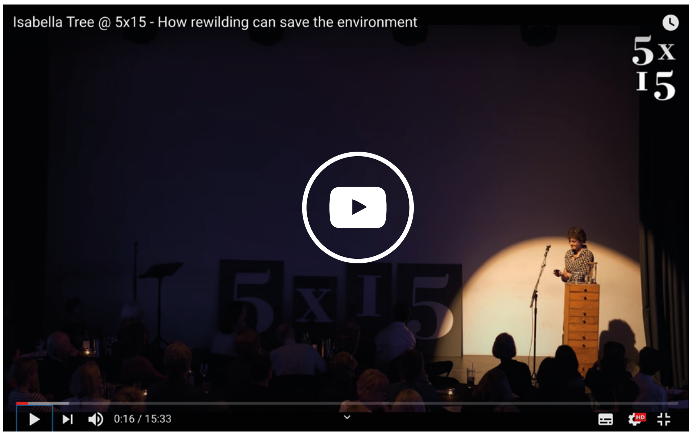

Sepp Holzer, Krameterhof
http://www.krameterhof.at
Sepp Holzer's
Permaculture
A Practical Guide for Farms, Orchards & Gardens

6.2. Other Case Studies

'Wilding' and Agro-forestry: the Knepp Case Study

Knepp shows us that animals are ecological engineers. Hardy English Longhorn cattle on land they have rewilded from arable cropping. In 2000, the owners of a large dairy and arable farm in southern England avoided the bankruptcy that threatens so many farmers by deciding to sell all their expensive machinery and follow a different pathway. Acutely aware of the degradation of land and loss of biodiversity caused by the 'conventional' agriculture they had been practising, they decided to join forces with an unconventional agricultural ecologist from The Netherlands. Frans Vera is convinced that much of northern Europe should be open-canopy woodlands with large expanses of wildflower meadows and grasslands created after the last ice age by ancient ungulates (hooved animals) that recolonised the land along with vegetation. Their behaviour created the landscapes and made it amenable for the wide diversity of wildlife that we are currently losing. At Knepp, the owners decided to use modern descendants of these hooved animals that mimic the behaviour of the ancient breeds





Watch this video in which Isabella Tree explains the process.

that are now extinct. They used hardy Longhorn cattle, Tamworth pigs, deer and Exmoor ponies, roaming free on the land, to trample and rootle and bring the soil and vegetation back to life. As a result, the land is succeeding to scrubby, wildflower grasslands with trees and wildlife has returned; we can see that animals play an essential role in rewilding and land management as ecological engineers. These animals have regenerated the land and must be kept on the land to avoid succession to closed-canopy woodlands, which are less species diverse and would, therefore, entail a loss of biodiversity. Knepp now produces a range of food products from the regenerated land.

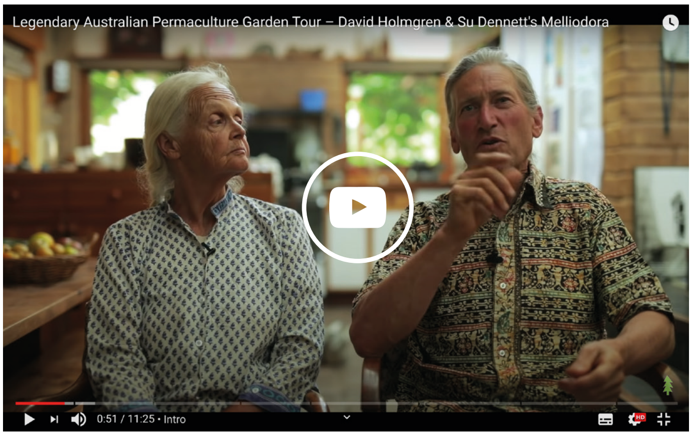
Mark Shepard: New Forest Farm

Alley-cropping is another form of agro-forestry with many benefits in terms of the mycorrhizal fungi that are maintained by perennials. For example, Mark Shepard's temperate climate permaculture project in Wisconsin, New Forest Farm, combines polycultures of productive trees with animals and a variety of annual or perennial crops. He used agro-forestry combined with permaculture design to restore land that had been badly degraded by decades by inappropriate annual cereal cropping.

In this video(14 mins) he explains the need to develop perennial staples for food security in a changing climate, and applying ecology, working with nature through succession to create a flexible but resilient system and ensuring a yield for income.

David Holmgren: Melliodora

While Shepard's farm is about 42 hectares, small-scale permaculture food forest projects are also possible in the peri-urban areas of large towns and cities, such as, David Holmgren's design for Melliodora on 2 hectares on the periphery of Hepburn, a small town in Victoria, Australia.



In this video (11 mins) of the property with David and his wife Sue Dennett, we can clearly see the potential for all aspects of permaculture as we deal with them in this dimension.

Eric Toensmeier: The Carbon Farming Solution

Back in the US, in a cold-climate permaculture project designed by Eric Toensmeier in his suburban backyard we can witness another range of potential for this practice. Toensmeier is one of the leading experts on food forestry and has co-authored the most in-depth books on the topic for cold and temperate climates. He is also a senior fellow at the Drawdown Project, a lecturer at Yale University and the author of the definitive work on carbon sequestration in farming systems, The Carbon Farming Solution. At home, his backyard food forest is remarkably productive.

In this video (14 mins), we can see how he has used the principles of permaculture in his design.

7. Conclusion

Quality drinking water is the first survival need for all human beings, followed immediately by health and high quality food and sustenance. In this Module we have not only reviewed a number of promising ancient and new approaches to growing food sustainably, we have also explored the importance of farmers as the guardians and stewards of landscape and humanity's right relationship with the ecosystems we inhabit. We have explored the importance of wilderness and the central challenge of the 21st Century: Earth Restoration through the conservation of the remaining enclaves of wilderness, as well as, the restoration and regeneration of the world's degraded grasslands, forests and rivers.

Today, a large proportion of our material culture – the products, clothes and materials we use – is directly or indirectly made from fossil fuels or by-products of the petro-chemical industry. If we want to re-design the human presence and impact on Earth away from fossil resources and degenerative impacts and shift towards plant-based resources and regenerative impacts, we will have to become Earth healers and restore and regenerate ecosystems, soils, and forests everywhere. This will fix atmospheric carbon in biomass and the soil, as well as, create a new basis for circular bio-economies based on regionally grown bio-resources and food. We will return to this topic in the economic design dimension of this course.