Undergraduate University Module in Permaculture – Student Coursebook

CREATING NEW SYNERGIES BETWEEN HIGHER EDUCATION AND PROFESSIONALS TO PROMOTE SUSTAINABLE SYSTEMS

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Undergraduate University Module in Permaculture – Student Coursebook

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- This student coursebook is intended for use as a learning support for students taking the Introduction Course to Permaculture as part of the Erasmus+ funded programme “Undergraduate University Module in Permaculture: Creating new synergies between higher education and professionals to promote sustainable systems (Acronym Perma +). It seeks to combine both theoretical material and practical case studies to create a unique and innovative tool for students who are following the course. The expected impact of this student handbook is to facilitate the delivery of the course by providing students with the main themes, topics, readings, and assignments involved in the module. It is the result of a collaboration and reinforced cooperation between academic institutions and organisations working on the field, namely: Safe Food Advocacy Europe – Belgium (as lead partner), Institutul de Cercetare in Permacultura din Romania (Romania), Universitatea de Stiinte Agronomice si Medicina Veterinara din Bucuresti (Romania), Università ta’ Malta (Malta), Accademia Italiana di Permacultura (Italy), Universita degli Studi di Catania (Italy), and Universita de Liege (Belgium).

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- This coursebook is divided into 7 volumes. Volume 1 is an introduction to permaculture and is intended to give an overview of permaculture, including its origins, the ethics and principles on which it is based, and regenerative agriculture, including urban permaculture. Volume 2 delves deep into major methods of design employed within permaculture. Volume 3 seeks to position permaculture as an adequate and important response to the climate change challenge. Volume 4 delves deep into the science of the soil, water, and fertility, as well as serves as an introduction to the various biogeographical regions, while Volume 5 focuses on science and the natural laws. Volume 6 goes deeper into pattern understanding and includes a database of patterns that can serve as an important discussion and inspiration on permaculture and design. Volume 7 contains different Student Tasks linked with each of the previous volumes. This coursebook is not intended to be followed in sequence but is designed in an interactive form that allows the student to move from one section to another according to need. Furthermore, it is understood that due to University requirements linked to different course descriptions, durations of courses, pre-requisites, and specific policies and practices, tutors or lectures might guide students to focus on specific parts of this coursebook. This is particularly a case in point since it is expected that such a course will be followed by completely different cohorts, some of whom might be following just out of interest as an option or elective, while others might be following such courses as part of a degree. Thus, some might be completely new to say soil science, while others might have studied it as part of their degree or previous studies. This coursebook is thus a repository of knowledge and experience that can be tapped into according to need. Even more, it is a friendly accompaniment to the student that has embarked on this exciting journey that is permaculture.

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Student Coursebook

Volumes 1 - 7

Perma+ Student Coursebook

- Volume 1 - Introduction to permaculture
- Volume 2 – Methods of design
- Volume 3 – Permaculture and the climate change challenge
- Volume 4 – Soil, water and biogeographical regions
- Volume 5 – Science and natural laws
- Volume 6 – Pattern understanding
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Student Coursebook: Volume 1 – Introduction to Permaculture

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Vol. 1 Introduction to permaculture

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Chapter 1: Permaculture - The Origins

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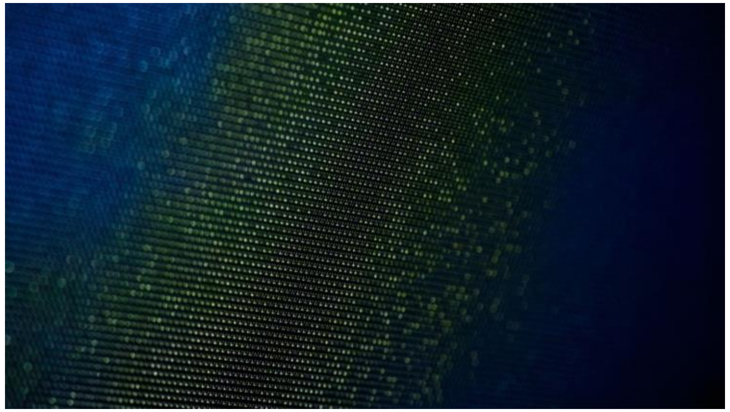
Origin of **Permaculture:** the Fathers

Permaculture as a Permaculture, is the union of two words: permanent and culture. This concept originates from the intuition of two men **Bill Mollison** and **David Holmgren**.

This concept describes the conscious design of ecosystems that are resilient, stable, efficient and regenerative.



Origin of **Permaculture:** the Fathers

Bill Mollison was born in 1928 in the small fishing village of Stanley, on the Bass Strait coast of cool-temperate Tasmania.

His work experience in different jobs in Australia allowed him to perform long periods of observation in the wild forests and coasts of Tasmania, closely monitoring the life of those ecosystems. In 1968 Mollison became a tutor at the University of Tasmania, in Hobart, and, later, senior lecturer in Environmental Psychology. It was in that role that he connected with a student at the Tasmanian College of Advanced Education, David Holmgren, and the seeds of Permaculture were sown.

In 1976 he published a 3-volume work on the *Tasmanian Aboriginal genealogies*.

David Holmgren was born in 1955 and grew up on the other side of the Australian continent in Fremantle, Western Australia, with political activist parents.

After graduating from John Curtin Senior High School in 1972 he spent a year hitchhiking around Australia before moving to Tasmania in 1974 to study environmental design with a special interest for landscape design, ecology and agriculture. It was during the brief but intense encounter between Mollison and Holmgren, that the backbone of the permaculture concept was formed.

Not all that long after devising the original concept of the permaculture design system, David started the work of setting up his rural smallholding – Melliodora — at Hepburn, a small town in Victoria.

Origin of **Permaculture**: the birth of a concept

Both Bill Mollison and David Holmgren have an academic background. Bill as a *sui generis* professor and David as a student.

Their work has always been closely related to a scientific academic and researchers' approach. While reading their published work, one can trace back the previous authors that they encountered and who inspired their work and future vision on permaculture design. Many of the ideas were already out there, in some ways scattered on a myriad of paths, well before the concept of permaculture design was defined by Mollison and Holmgren. However, the first time the word permaculture in its definition as an ecological design method is used can be traced back to an article published in 1976 in *Tasmania's Organic Farmer and Gardener* newsletter published by the Tasmanian Organic Gardening and Farming Society. It was titled *A Permaculture System for Southern Australian Conditions – Part One* and was written by Bill Mollison and David Holmgren.

The crucial publication of a report commissioned by the Club of Rome and published in 1972 (*The limits to growth*) played a huge role in the birth of the concept of Permaculture, summing up data and information describing a computer simulation of the consequences of exponential economic and population growth with a finite supply of natural resources. That report and the oil crisis of the 1970s opened the eyes of many concerned about human footprint on the planet about a harsh reality: **change in our way of living and connecting to natural resources and ecosystems was radically needed**.

The real explosion of interest towards the 'Permaculture' concept, came with the publication by Bill Mollison of ***Permaculture one: A Perennial Agriculture for Human Settlements*, in 1978**.

Origin of **Permaculture**: the birth of a movement

The Aborigines and Torres strait islanders of Australia have to be evoked. They were already practicing a permanent culture. The importance of indigenous cultures and knowledge for permaculture is clear if we refer to the knowledge and know-how that have been accumulated across generations and which guide human societies in their innumerable interactions with their surrounding environment. Permaculture in some ways has been around for the past 10,000 years in many cultures as a way of living and connecting to nature. Well before Mollison and Holmgren defined the concept of designed permaculture, **original permaculture** was practised worldwide in regions where western innovation had not set foot.

Mollison and Holmgren's ideas leading to the '*birth of permaculture*' as a concept can therefore be described as **designed permaculture** compared to that **original permaculture**.

Bill Mollison himself set sail to travel around the world. Teaching, researching and creating the basis for an international movement that has grown incredibly in the last forty years. Mollison first created a curriculum to teach permaculture design locally in Australia, forming the first permaculture teachers.

The first Permaculture Design Course (PDC) that Bill Mollison taught took place in Germany in 1982. It was followed by many others on different continents.

Mollison also refined its design system approach, publishing *Permaculture two: Practical Design for Town and Country in Permanent Agriculture* (1979), and worked on the systems thinking approach to design what is at the basis of the curriculum, later defined in the *Permaculture, a designers' manual* (1988).

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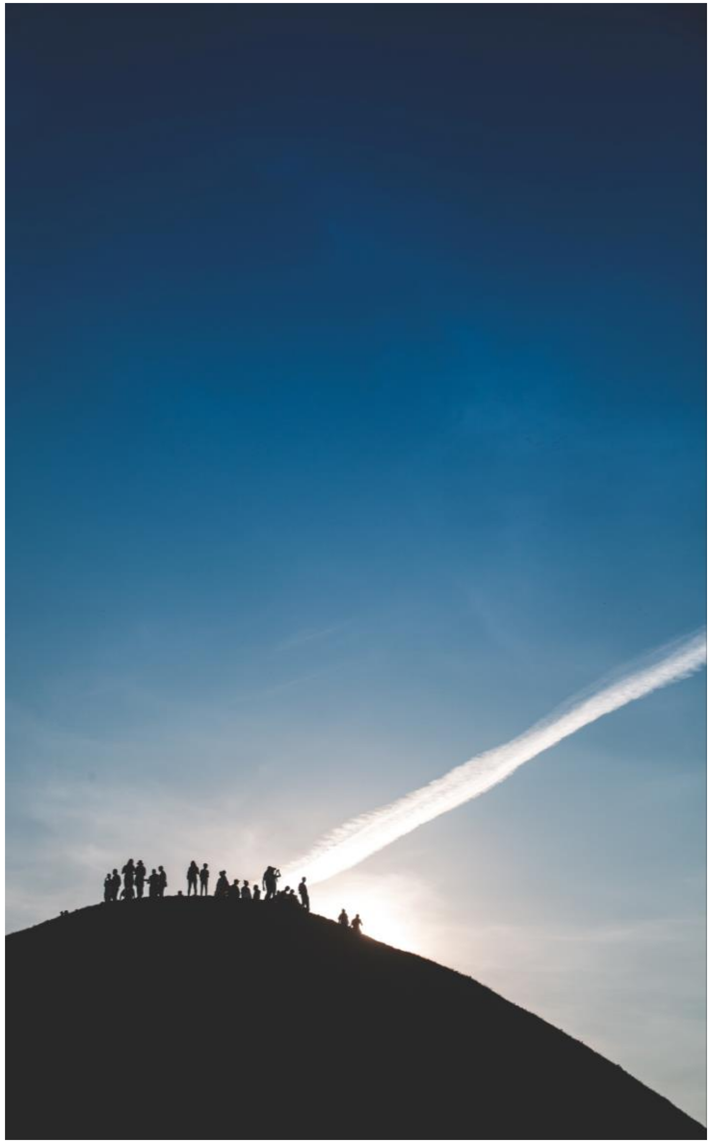
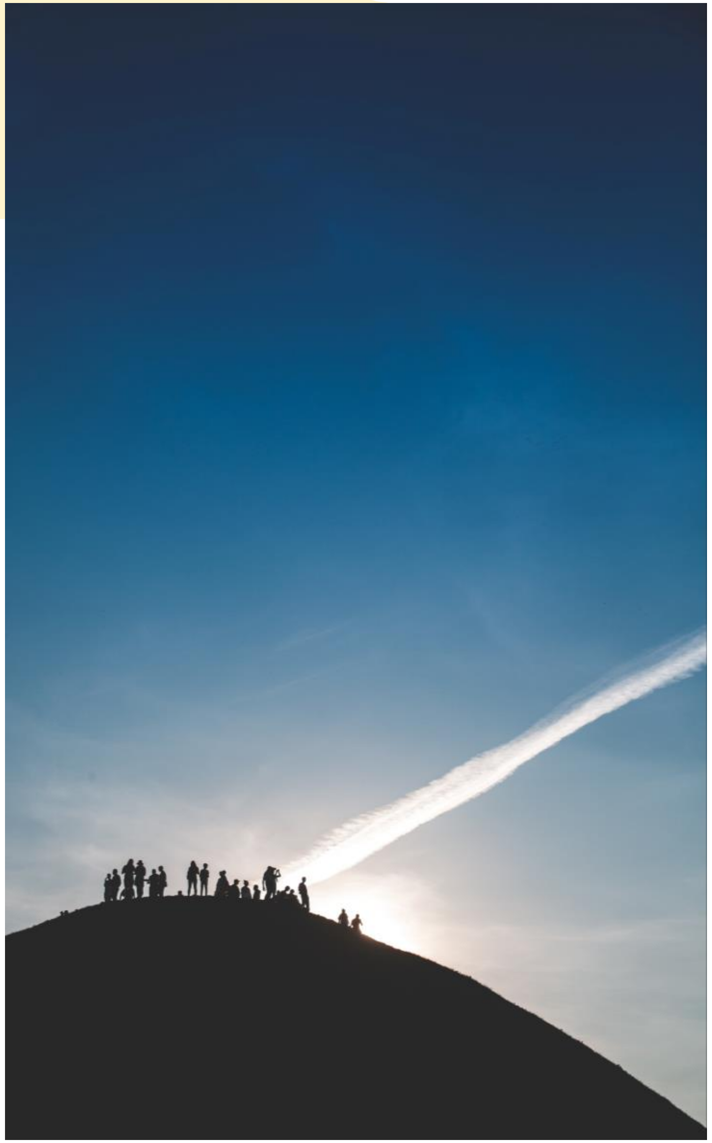




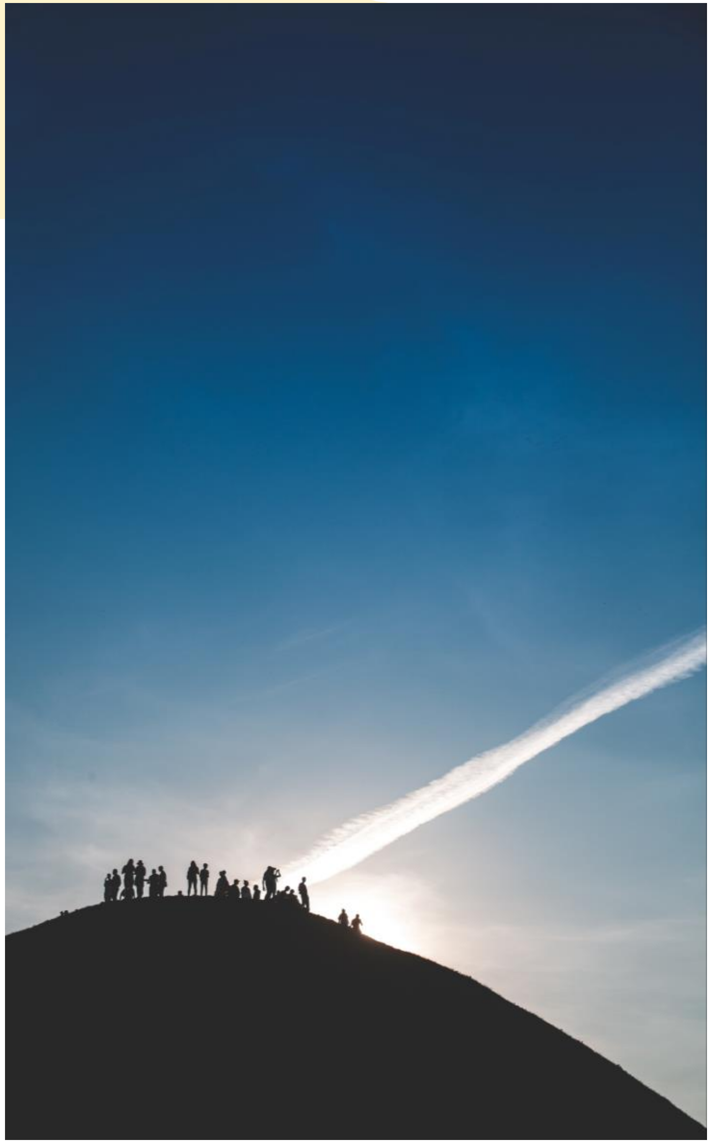
Origin of **Permaculture**: the birth of a movement

Bill Mollison travelled extensively and connected with many different ecological design projects and institutions. The great force and energy of Bill Mollison led to the birth of an **international movement** that organised international meetings from its first years on.

Nowadays, over 1,000,000 people are certified in permaculture in more than 140 countries, with more than 4,000 projects on the ground. Although the numbers are impossible to verify, it is clear that the global movement is continuously creating more projects in the most diverse fields.

The international permaculture movement has grown and crossed various phases. The underlying aspect we can trace throughout its history, is that it is a **decentralised movement**, even if there has been a predominance of certain associations (globally, the Permaculture research institute of Australia, or the Permaculture Association in the UK). What keeps the movement together is the **common acceptance of the first directive of permaculture**: take personal responsibility for one's actions, and the three ethics of Permaculture.

Permaculture design has grown exponentially, and today we can see it applied not only in rural settings, but also in urban areas with a social aspect.



Women and permaculture

If we look at the history of permaculture design, **women** in permaculture should not be forgotten. In the last years a movement of women that practice permaculture has got together focusing on the study of permaculture design, focusing on female authors, and giving them the right recognition, and underlining the importance of expressing oneself in a safe space.

Very little international recognition has been handed to women amongst permaculture practitioners, although many if not more pioneers in permaculture are and were women. The book *Permaculture pioneers* (2011), edited by Kerry Dawborn and Caroline Smith famously recalls that many of the Australian pioneers are women.

The Permaculture movement acknowledges that it is still male-centred and still has significant amount of work on the social aspects of permaculture design, focusing on gender realities. The truth is that we as individuals and groups have to keep on working on **inclusion**.

For inclusion, we have to work on focusing on who is excluded creating specific, focused spaces for teaching.

Interestingly, in the first issues of the *Permaculture International Journal* in 1981, PDC proposals were often made for women, which were contributing in groups to the movement. New Women groups for permaculture are being formed today, meaning that the issue of inclusion in the movement has not yet been solved.

Chapter II: Ethics and Principles

AN INTRODUCTION TO THE ETHICS OF PERMACULTURE

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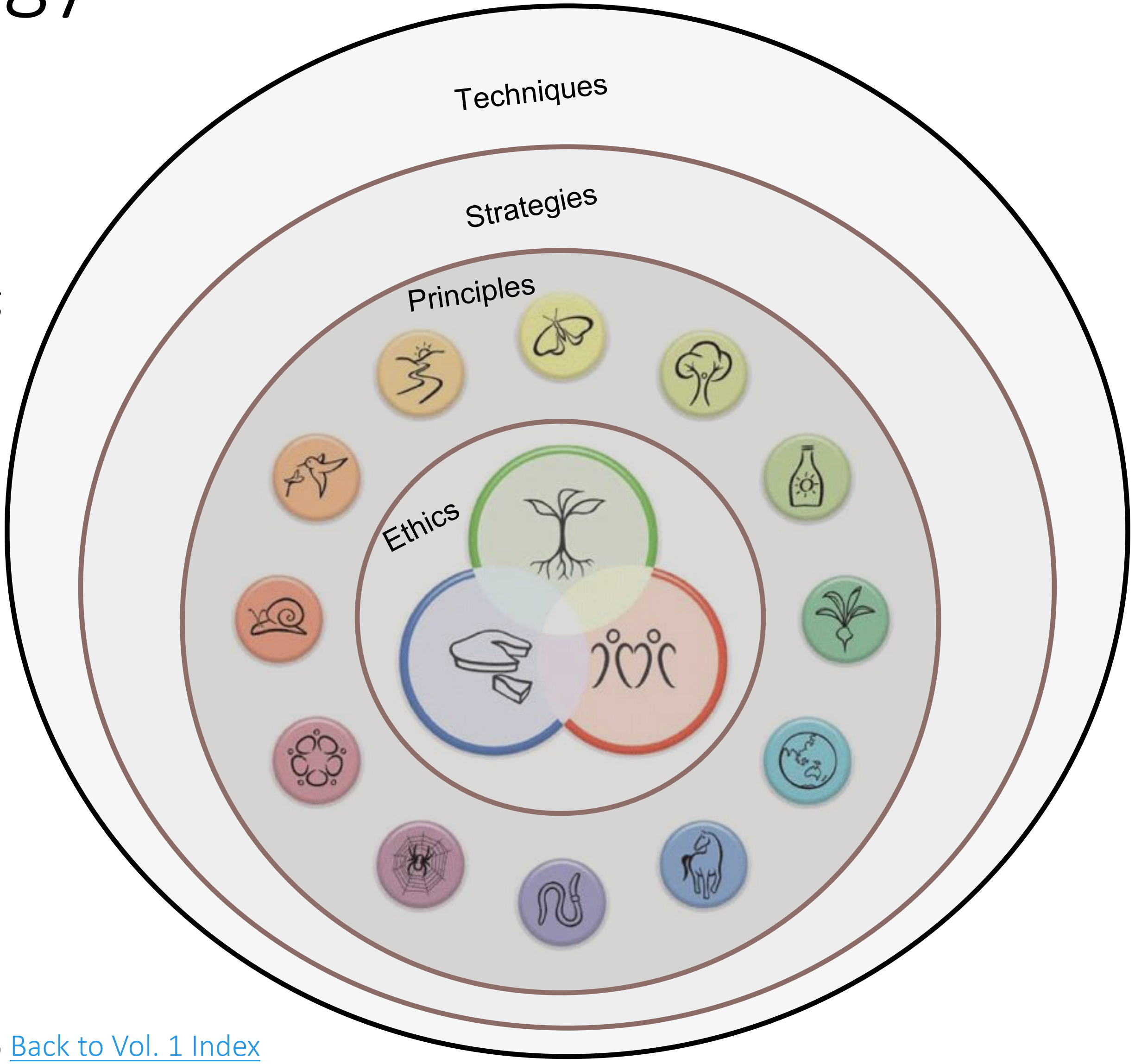
Permaculture Methodology

A Permaculture design Methodology is defined by the following elements:

1. Ethics and Principles
2. Design Process
3. Design Tools
4. Deliverables/Outputs



Ethics and principles of Permaculture

Ethics and Permaculture

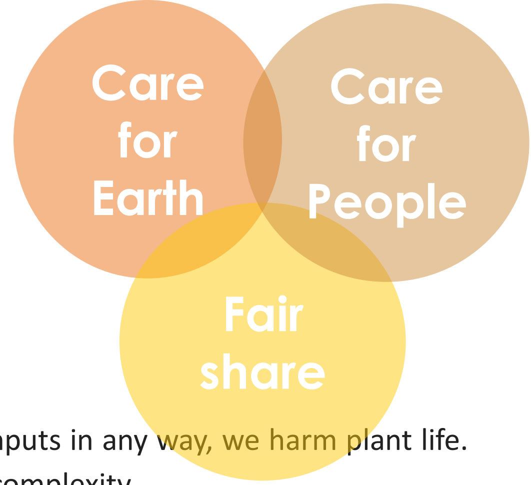
Ethics is one of those terms that people know but cannot exactly define. In common usage, the word "ethics" is often incorrectly used interchangeably with the word "morality", and although the two concepts are tied together, they are not the same. Whereas morals define what is right and wrong, ethics are a codified or formalised system of morals of a particular person, group etc. So, in a nutshell, ethics can be defined as a set of formalised principles of what is right and wrong conduct.

As a basic definition, **Permaculture** is a holistic design system set up to create sustainable human settlements and food production systems. It is also a global movement concerned with the sustainable, environment-friendly use of the land and the building of stable communities, through the harmonious interrelations between humans, plants, animals and the Earth.

By this very definition**, this system requires that our conduct is focused on the good of the planet**, of Nature and of the people. It cannot work otherwise.

Permaculture deals with scientifically definable and measurable systems, biological ecosystems and human communities. What is beneficial or detrimental to either of these systems is not a subjective matter bound in the realms of personal opinion and conjecture. What is good or bad for living systems is objective scientific fact that can be observed, measured and the results readily reproduced, it is not idle philosophy abstracted from reality and relegated to the towers of academia.

Ethics and Permaculture



"Any living system, when viewed scientifically, has required inputs which sustain life within that system".

A plant needs sunlight, air, water and soil to sustain it. Naturally, these inputs occur in a clean, unpolluted state. If we impair these inputs in any way, we harm plant life. When we extend this example to animal life (and yes, that includes us humans too!), it works exactly the same way, just with greater complexity.

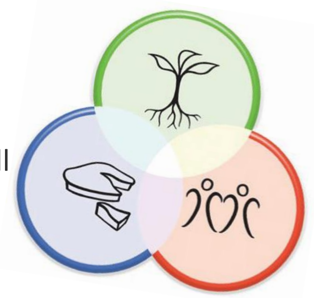
If people's actions are detrimental to the inputs required to sustain life in a living system, or if the actions are directly harmful to the living system itself (ie. the organisms within it), then those actions are *de facto* **unethical**.

From a Permaculture perspective, ethical actions are therefore simply those that support life, while unethical ones are ones that harm or needlessly destroy life.

Permaculture therefore starts with ethics, which form the very **foundations of this design system**, and all actions we undertake in

The three ethics of Permaculture are as follows:

- **Care for the Earth**
- **Care for People**
- **Return of surplus to Earth and people** (also called "**Fair Share**")



The ethics of Permaculture, Care of the Earth, Care of People and Sharing of Surplus, promote a system that is life-affirming, and creates a sense of reverence for all on the planet.

By embodying and living by these principles, we ensure the continued survival of our species, the health of the planet and maintain a healthy respect for life itself.

Ethic 1: Care for the Earth

The Earth is the very thing that sustains us, it provides us with all the essentials that keep us alive (air, water, food, shelter) and it is the only source of these essentials, we cannot get them from anywhere else. We depend on the Earth and all the living systems on the planet (which, incidentally, are all interconnected in a complicated, interdependent web of life) for our survival.

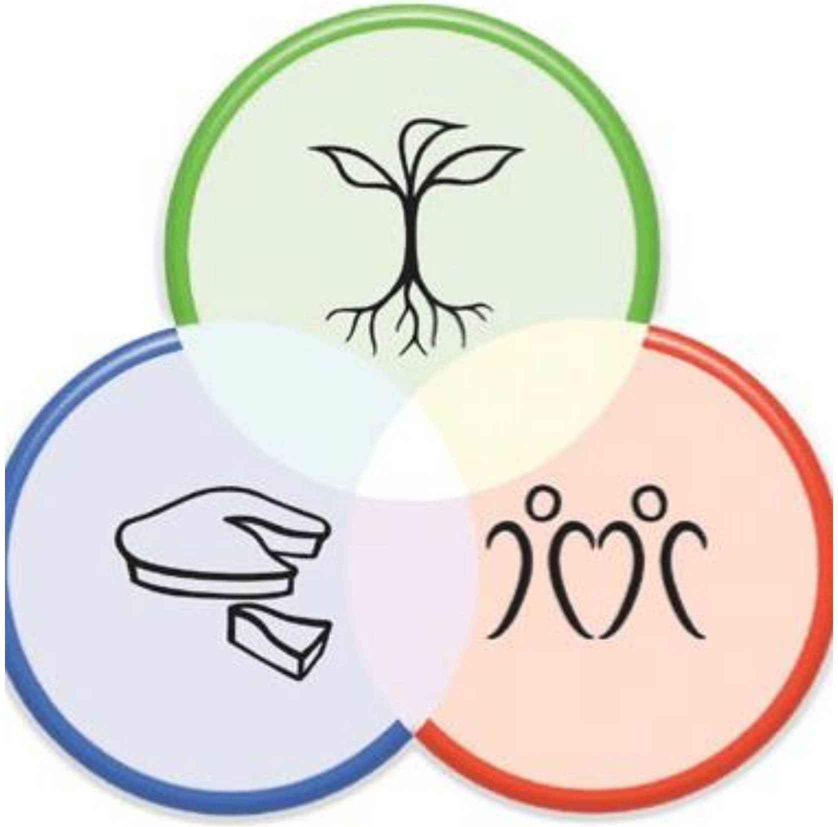
Taking care of the Earth's systems, which keep us alive, would logically be seen as "**enlightened self-interest**", in other words, doing what is right to ensure one's own survival, though not polluting the air we breathe, not poisoning the water we drink, and not destroying the land which provides our sustenance.

"Care of the Earth" includes all living and non-living things, such as animals and plants, as well as land, water and air.

Why? As science shows us through the disciplines of ecology and biology, all living and non-living systems are interconnected and interdependent. When one is affected, all are affected.

Caring for the Earth also means caring for the soil. Life depends on life, and the soil itself is actually a very complex living ecosystem, which supports plant life. Plant life in turn supports higher organisms and provides us with our sources of food, directly or indirectly.

Beyond food production, caring for the Earth means caring for our forests, which are the lungs of the planet, ensuring a supply of clean air. Forests are also inextricably linked to the process of rain formation and the water cycle, and therefore play a key role in ensuring our supply of fresh water. It means caring for our rivers, which are the veins of our planet, circulating the water, which all life depends on.



Ethic 2: Care for People

All living things are interdependent, and this includes the people. In reality as the saying goes, "*no man is an island*", humans by their very nature are communal and social animals. Life on this planet is generally cooperative in nature.

Beyond physical interdependency, humans psychologically ***need*** a community. Modern studies have shown that having a community is beneficial to the mental health of an individual, while the lack of a community is clearly detrimental.

Self-sufficiency **is a myth,** ***and a harmful one too!***

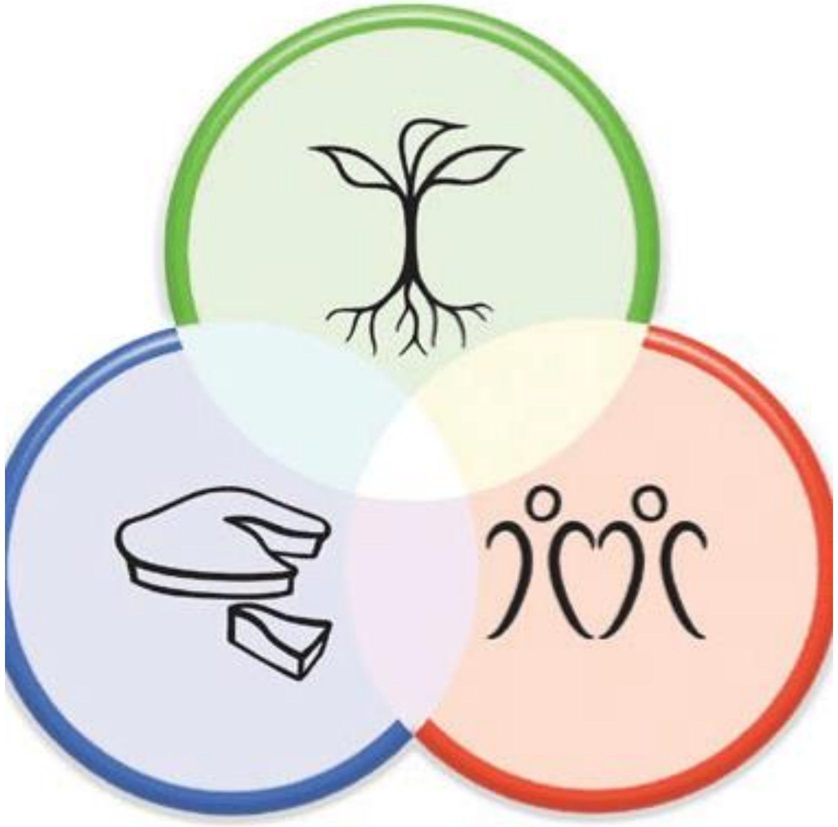
"Care of the People" is about promoting responsibility towards the greater community. It is important to point out that we are talking about *self-reliance* and *not* self-sufficiency here. As mentioned above, "*no man is an island*", one person cannot do everything, and it would be ridiculous to expect any one person to do so in any lifestyle.

As Bill Mollison once stated, "*I might grow food, but I don't want to have to make my own shoes, I can trade food I've grown with someone who makes shoes*". That is the essence of community! It is about sharing and supporting each other.

So, what does promoting self-reliance mean? It is about taking responsibility for more than one's own future and looking to help one's community by sharing knowledge and experience, to teach people so that they can provide for some of their basic needs.

The essence of this is captured by the expression "*give a man a fish, and he'll eat for a day, teach a man to fish and he'll eat for ever*". It is about a collaborative effort to bring change to one's own life and that of others.

When people collaborate to support each other, and to meet their needs, both physical and non-physical, this creates a bond, which builds a stable, supportive, emotionally healthy and prospering community.



Ethic 3: Fair share

This is also described as the ethical principle of "***Return of surplus to the Earth and people***". No matter how you look at it, the world's resources are finite, so logically **there is a finite and measurable share of resources available to each person on the planet**.

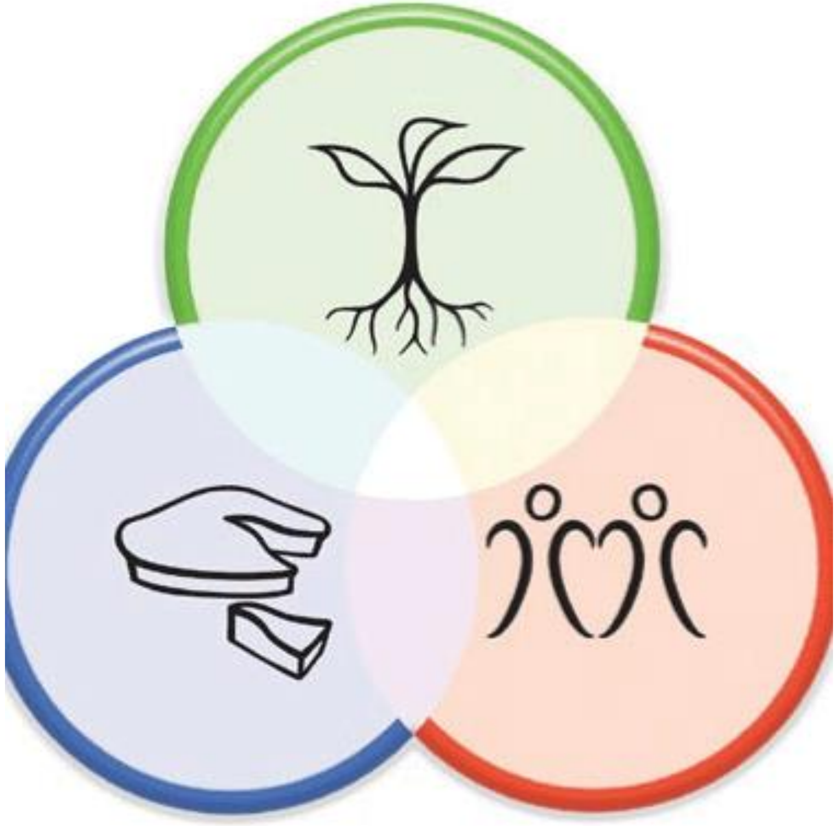
If all the produced resources were a metaphorical "pie", and each person had their "slice of the pie", what happens when someone wants more than their fair share, when someone wants more than one slice of the pie? Simply put, someone else goes without.

If anyone for even the briefest moment stops to think of how you could possibly have continuous growth, and for that matter, continuously increasing consumption, on a planet of a fixed size with finite (and diminishing) resources, then the nonsensical nature of this concept becomes clear and evident.

All our basic needs are met by the Earth itself, and our higher needs are met through community with each other.

Furthermore, when we share our surplus and when we share our skills, knowledge and experience, we build bonds between people which helps in fostering a sense of a stable and collaborative community.

So, what's the point of "Fair Share"? If we take only our fair share, then there is enough for everybody, and there will continue to be in the future too.



Principles and Permaculture

Three categories are listed below :

[Attitudinal Principles]

[Holmgren Principles]

[Design Principles]

Permaculture is a multi-disciplinary design science based on a set of economic (fair share and the redistribution of surplus), ecological (Earth care) and socio-cultural (people care) ethics, as well as on a set of **ever-evolving design principles**.

Its vision is to find a **balance between mankind and nature**, and to implement productive, inclusive, regenerative and abundant survival systems so as to permit the abundant and balanced coexistence of man as both steward and resident of his surrounding environment.

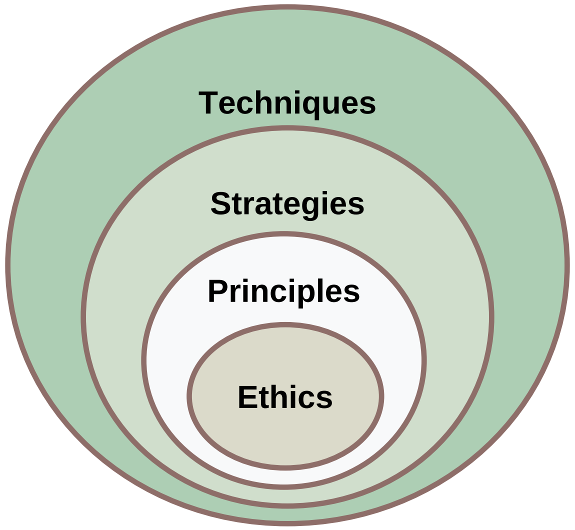
Permaculture's Ethics and Principles are the foundation for the methods of design and act as checks and balances so that even the most complex project or system is simultaneously regenerative for man and nature.

The Permaculture design principles are a set of universal design principles that can be applied to any location, climate and culture, and they allow us to design the most efficient and sustainable human habitation and food production systems.

Each individual design principle itself embodies a **complete conceptual framework** based on sound scientific principles. When we bring all these separate principles together, we can create a design system that both looks at whole systems, the parts that these systems consist of, and at how those parts interact with each other to create a complex, dynamic, living system.

Each design principle serves as a tool allowing us to integrate all the separate parts of a design, referred to as elements, into a functional, synergistic, whole system, where the elements harmoniously interact and work together in the most efficient way possible.

Attitudinal principles



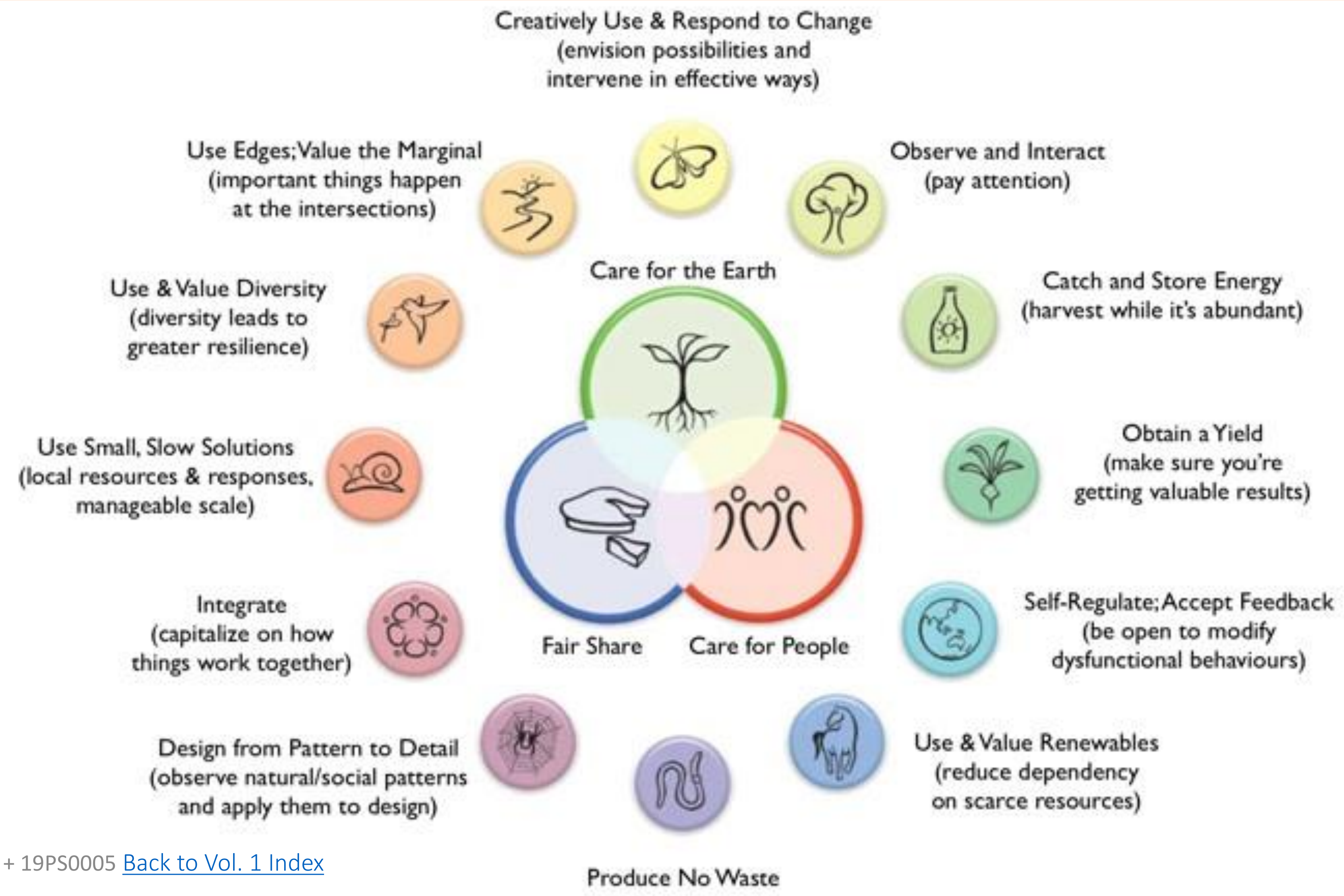
The permaculture movement cares about design and people, therefore it is worth highlighting some of the principles that can have an effective application during the design process and life itself.

Some attitudinal principles are listed below:

Please take a moment for each of the following principles to think about how they can be experienced or maybe how you already experienced them in your life.

- Everything influences everything - Everything works both ways
- Work with and against
- No Action – Think 3 and Do 1
- The problem is the solution
- Start from your doorstep
- Work where it is more effective
- Cooperation and not competition
- Think Global and act local
- No Fun…No Permaculture!!
- Be Lazy – Let nature work for you
- The only limit we have is imagination
- Work once, think twice

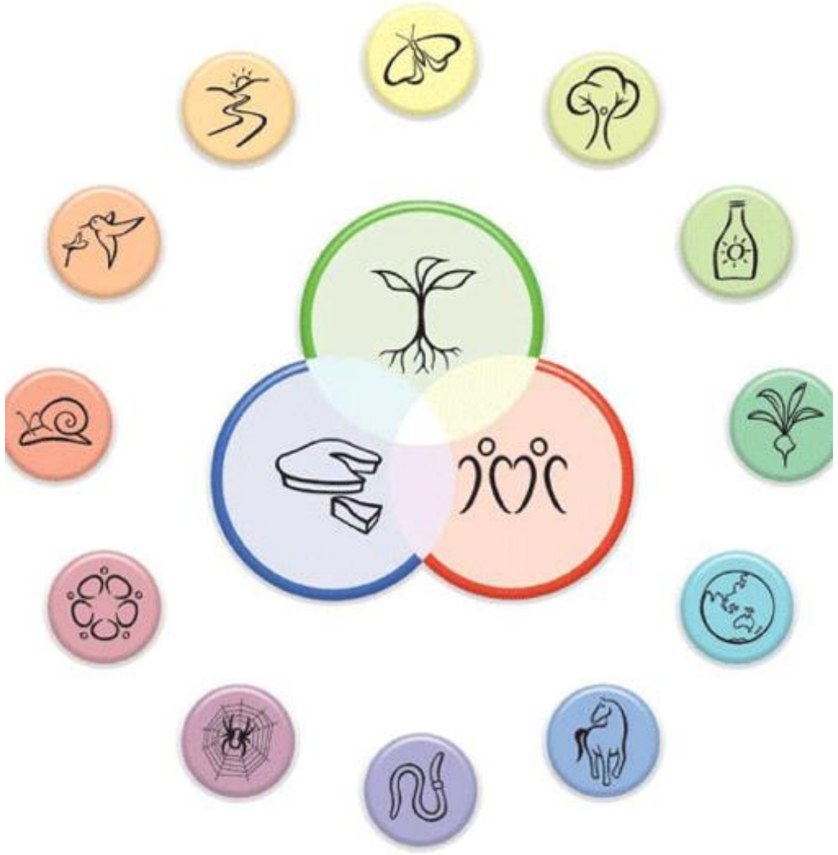
Design Principles - Holmgren



Holmgren’s principles

David Holmgren defined **12 principles behind permaculture revolving around the three ethics**, listed and explained in the following section:

1. Observe and Interact – “Beauty is in the mind of the beholder”.
2. Catch and Store Energy – “Make hay while the sun shines”.
3. Obtain a yield – “You can’t work on an empty stomach”.
4. Apply Self-Regulation and Accept Feedback – “The sins of the fathers are visited on the children of the seventh generation”.
5. Use and Value Renewable Resources and Services – “Let nature take its course”.
6. Produce No Waste – “Waste not, want not” or “A stitch in time saves nine”.
7. Design from Patterns to Details – “Can’t see the forest for the trees”.
8. Integrate Rather Than Segregate – “Many hands make light work”.
9. Use Small and Slow Solutions – “Slow and steady wins the race” or “The bigger they are, the harder they fall”.
10. Use and Value Diversity – “Don’t put all your eggs in one basket”
11. Use Edges and Value the Marginal – “Don’t think you are on the right track just because it’s a well-beaten path”.
12. Creatively Use and Respond to Change – “Vision is not seeing things as they are but as they will be”.



1. Observe and interact

"Beauty is in the Eye of the Beholder."

Before mankind developed the ability to gather, store and transmit knowledge through oral and written culture, the most basic way to know our surroundings was through **our five senses**: to smell a forest fire or the scent of a passing Mountain Lion, to feel the texture of ripe fruit and to hear the sound of flowing water through a canvas of trees.

The ability to read the landscape, interpret and transmit information about it contributed massively to the evolution of humankind and our ability to survive and thrive in nature. Life in the contemporary urban & peri-urban society has severed the connection to nature.

In design, **observation** and **analysis** precedes applied design at any scale and is periodically reiterated. The observation process yields vast understanding of patterns, details, energy flows, functions, elements, connections, material and socio-cultural contexts, variance in time and space etc. The observation process informs the designer about the project's context and guides us to work with nature, rather than against it.

Prudent, incremental, creative and strategic interaction is highly advisable in ultra-complex ecological systems, where every action can have heavily amplified, potentially destructive, unforeseen consequences. **Observation and interaction imply a bidirectional process between subject and object**, the designer and the system. Since thoughts are often conditioned by values, culture and preconceptions, it is very useful to refer to the attitudinal principle that can help in avoiding getting caught in the trap of dualistic thinking.

***Example**: Design is based on calculated reality. To design a system to catch water, we can observe how rain falls in a barrel from a roof.*

2. Catch and store energy

"Make hay while the Sun shines!"

Energy is the basis of the life. In every aspect of our lives, we are influenced by various forms of energy (gravitation, electromagnetism, wind, sun, etc.), whose general tendency is towards increasing entropy (increasing chaos through conversion processes – thermodynamics' second law).

The concept of "**syntropy**" describes the opposite of entropy. When order increases, syntropy increases. Biological phenomena and living systems are regulated by a principle of finality tending to originate increasingly orderly and differentiated systems. They are thus characterized by increasing syntropy. One of our most important tasks as practitioners of a regenerative culture is identifying energy flows and guiding them through the systems we manage, so as to achieve a regenerative outcome.

I can catch the Sun through a solar system and store heat in water (ex. In a boiler), or in walls. I can use roofs to catch rainwater and store it in tanks or accumulations, or create organic matter traps along the edges of the road to create accumulation areas. People are also a form of energy, so creating condition to people's wellness and good relationships is a way to keep a form of energy that can always be useful.

This principle stimulates us to **design ways to capture the advantageous forms of energy** that enter the system, and retain them as much as possible before letting them out; the example of **the ball in a pinball machine** gives the idea.

One of the most important activities of mankind should be to adapt the landscape to fulfil various functions related to the storage and utilization of large quantities of energy, materialized into natural capital and infrastructure in elements such as: timber, hedgerows, orchards, perennial plantings, dams, ponds, hummus, mulch, compost, living structures, natural housing, etc.

3. Obtain a yield

"You can't work on an empty stomach."

"Obtain a Yield" recommends that, as careful stewards, managers and gardeners, all of the systems under our care should produce a tangible yield.

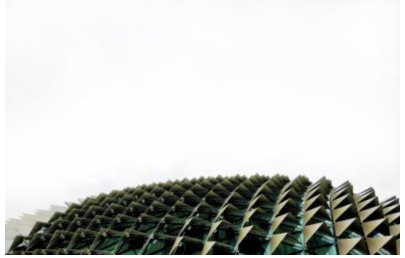
A house, a garden, a school etc. have the potential to be made up of elements with the potential to ensure a yield of vegetables, aromatic and medicinal plants, honey, etc.

Bill Mollison believed that "*the yield of a system is, theoretically, unlimited*", or just limited by the imagination and creativity of the designer. Measuring the energy footprint and balance (input vs. output) is done initially through auditing the 8 forms of capital: financial, material, natural, social, intellectual, experiential, spiritual and cultural. Permaculture's ideal production system is a diverse one, in opposition to the conventional monocultural production technology.

Permaculture design aims to produce yield while adding value by building on the project site's natural potential (ex.: building a pond in a low, often flooded area).

Complete self-sufficiency is quite impossible, because we are unable to create sufficient capital of each type so as to wholly satisfy our needs. The optimal strategy is therefore **to develop forms of production**, whose maintenance does not depend exclusively on external inputs. For the rest, we should become participants in local exchange systems, which keep the fabric of society strong.

4. Apply self-regulation and accept feedbacks



"Make lots of small mistakes" / "Fail Fast"

Complex and resilient systems evolve through integration and adaptation to tensions, which appear in their processes. The simplest self-feedback mechanism is **self-analysis**: defining our current reality, our needs and processes through which we fulfil them, our desired quality of life.

No matter if it relates to ourselves or the exterior, feedback must be taken with an open heart.

Jumping in head-first into a large-scale project requires **experience**.

Holmgren's principles

5. Use and value renewable resources and services

"Let Nature take its course."

The main characteristic of renewable resources and services is their capacity to **recover and renew themselves** through natural processes, within a reasonable amount of time, without the need to constantly reinvest non-regenerable inputs for their proper manifestation. Renewable resources and services represent Passive Income, while non-renewable one's demand investment costs.

Permaculture endeavours to optimally utilize renewable resources to create diverse systems, with a high productivity and resilience in time, even if the project implementation process requires the investment of non-renewable resources. Presently the tendency in industry is to consume non-renewable resources while depleting renewable resources, thus ending their lifecycle and potential future yields.

This Permaculture principle honours the abundance and the value of natural resources and ecosystem services in the perspective of **reducing consumption and dependence on non-renewable resources**.

Permaculture system management focuses on the prosperity of natural, passive ecosystem services and renewable yields and ensures the stability and interconnectedness of their niche within the system.

***Examples:* Natural purification and oxygenation of water in nature through natural flow, streams, natural dams and ponds, wild berries, other seasonal wild yields, flower patches etc.**

6. Produce no waste

"Waste not, Want not."

This Principle encourages simplicity and taking responsibility for our consumption footprint and pollution through an approach, which regards waste as a resource and an opportunity. Waste in nature does not exist, it is something introduced by man, deriving from linear processes focused only on the consumption phase which are not very efficient. In natural systems all processes are cyclical, someone's waste is a resource for someone else, in an infinite series of linked actions or exchanges.

Permaculture looks closely at the input-output cycle and tries to use up as much potential energy as possible.

This can be translated into practice with the following operational guidelines:

a) Design with the entire life cycle in mind

b) Refusal and reduction

c) Reuse

d) Repair and maintenance

e) Recycling

6. Produce no waste:
a. Design with the entire life cycle in mind

Any structure or object you want to create has a life, which begins with the extraction of the raw materials that make up the materials that compose it, and ends with the exhaustion of its functionality.

Getting information on the **origin** of the materials, the **functioning** of the object and **how it can be dismantled** or disposed of in the end will help to understand how much and which type of waste is produced in the three phases, and this will guide our choices to contribute as little as possible to the production of the waste that we cannot see, but which can be found both upstream and downstream of what we use.

As an example, in some cases it may be preferable to choose wooden frames rather than aluminium, considering that wood is a renewable resource while aluminium involves a destructive extraction process with a large production of toxic waste.

6. Produce no waste:
b. Refusal and reduction

It refers to refusing and reducing unnecessary consumption.

Getting used to being at a temperature of 17-18 °C instead of 20 ° in an indoor environment reduces consumption for winter heating. The installation of compost toilets and cisterns for rainwater collection can reduce or eliminate the need for civilian water supply tanks.

6. Produce no waste:
c. Reuse

Reusing an object for the same purpose for which it was designed or for secondary uses is a way to remove materials from landfills, as well as having low-cost materials.

The possibilities to reuse are endless and there are various examples out there of creative reuse with many different materials and objects.

Punctured bath tubs can become containers for the vegetable garden or compotes, beer bottles can be used to store homemade tomato sauce, while cans of cat food can become seed containers, and so on.

6. Produce no waste:
d. Repair and maintenance

Repair is a hardly used practice today, forgotten and even opposed by the industry that puts objects of little value specially designed not to be repairable on the market, in favour of growth in consumption. Until a few decades ago, valuables were repaired with care, and figures (in extinction) such as the shoemaker are evidence of this.

Repair is a natural process, just think of the wound healing process of the human body, or the earth's ability to recover by restoring the destroyed vegetation or soil degraded by a particular disturbance (e.g. colonization of a lava flow by plants).

Maintenance extends the life of the objects, if carried out properly, avoiding deterioration which jeopardizes the possibility of repair.

6. Produce no waste:
e. Recycling

This is the process in which a material is broken down into its basic constituents. It is the most publicized strategy for waste prevention, despite involving processes with high-energy consumption and in any case achievable only up to a certain degree; in fact, not all materials, like plastic, are infinitely recyclable.

Yet **recycling is what happens constantly in natural systems**, where substances are decomposed into the simplest elements by organisms such as earthworms and bacteria, and reassembled starting from assimilation by plants, when they are compatible with life forms. This provides indications in favour of the use of eco-bio compatible materials.

The **application of natural design principles to biodegradable materials** could greatly reduce the negative impact of Industry on the environment and diminish the pressure on Non-Renewable Resources.

7. Design from patterns to details

"Can't see the forest for the trees."

Natural and social patterns are a source of inspiration in Permaculture because they allow us to **conceptualize processes** and utilize systems thinking: making sense of complexity and expressing it in a simple, predictable and repeatable way.

Patterns become frameworks and ways of ordering and help organize a highly complex system into its components and subdivisions, aiding in design work.

Patterning goes from surface to the details. After seeing the basic patterns of a complex system we go deeper and look at interdependence, interactions and processes between its parts, the type of energy they consume & produce, cycles and their frequency, etc.

There is a misconception that Permaculture is about elements: pizza ovens, rocket stoves, swales, huge beds. However, **Permaculture is about looking at the master pattern and determining what element fits naturally and effortlessly into the system**.

***Examples of patterns and frameworks**: the pattern of time and scale of intervention - scale of permanence, the pattern of space: sector analysis and zone analysis.*
***Examples of patterns and their use**: The forest ecology as a model for soil-building and food production, the interactions between animals and plants as a model for Pest prevention and soil fertilization*.

8. Integrate rather than segregate

In Ecology, the relationships between the elements composing an ecosystem are at least as important as the elements themselves. A vibrant, healthy ecosystem is the consequence of a totality of meaningful, qualitative and beneficial relationships and connections between elements, not by the simple sum of elements. **Permaculture aims to integrate elements** in a polarity: so that the Needs of one element are met by another, and vice-versa.

Permaculture goes even further and examines the waste to nutrient equation, figuring out how to use the waste from one assembly of elements to power or fuel another assembly with different characteristics, ensuring the illusion of endless energy, which is, in fact, just cleverly transformed through natural processes.

In order to increase system resilience and to decrease the chances of failure or disaster, every important element for the functioning of the system should fulfil several functions to offer the system positive redundancy (a state where an element failing to deliver can be complemented by another element which will automatically fill in the gap to maintain systemic stability).

Therefore, Permaculture looks **at elements**, **their functions**, but also at their **placement** and **interrelationships** to figure out how the system actually plays out and to **predict its evolution and lifecycles** over the years to come.

***Example of Functions**: Through its natural behaviour, a simple flock of chickens can offer us brilliant company, wonderful clucking around the yard, eggs, meat, warmth, feathers, pest control services, compost processing services, while they also need elements to express themselves comfortably and in good health: a balanced diet, shade, wind protection, pasture, shrubbery, protection from predators, a nest etc.*

9. Use small and slow solutions

"Small is Beautiful"

The principle invites **simplicity** and responsibility for human and material resources. Reasonably-sized solutions have a higher probability to fit into the managed system.

Their application can best be seen in Project Management. **Small and slow solutions are easier to implement** and maintain than large, revolutionary ones, and are, often, used as learning instruments: how will the system react to incremental change?

Example*: *Taking on large-scale projects requires experience and solid project management skills. Attempting this at the start of your design career might mean an early dose of discouragement. Rather than that, start off with a smaller-scale project: try designing your terrace, backyard or relatives' properties or try putting together a group and start a community garden or small farming enterprise.

10. Use and value diversity

"Don't put all your eggs in one basket."

Diversity increases resilience to adverse conditions (climate, pests, extreme weather) and offers stability and protection.

Permaculture teaches that we should always have a **diversity of approaches** to design, and we should reinforce our systems with a variety of plants, animals, structures, elements, functions, yields, etc., which have a variety of roles and relationships.

Diversity is an interesting **insurance policy** in case of extreme uncertainty and guarantees that, in the end, there will be enough to support the evolution of the system and to harvest. Natural ecosystems are wild, diverse and offer a modest but steady yield, while artificially-implemented systems are more management-intensive, yield faster, but with greater Investment costs. A combination of both is favourable.

The sum of the yields and the resilience of a polyculture is greater than the energy created by a monoculture within the same space.

11. Use edges and value the marginal

Optimize edges. The edge (**the intersection of two environments**) is the most diverse place in a system and is where energy and materials accumulate or are translated. Increase or decrease edge as appropriate.

"The Edge is where the Action is"

"Don't think you're on the right track just because it's a well-beaten path"

The transition zone between two neighbouring ecosystems has a greater productivity and diversity than each of them separately. Many familiar species, including humans, prefer to inhabit these edges to benefit from this abundance of habitat and nutrients. Despite being abundant, competition for resources, nutrients, light, water and food is more intense on the edge.

The ecotones are examples of marginal areas. These are intermediate spaces between two adjacent ecosystems, such as river estuaries and riparian strips.

If we consider a tree, we will have the opportunity to observe that most of the life takes place in the foliage on the border between air and biomass, and at ground level between air and earth. The presence of two environments (e.g. air-soil) increases the opportunities for life forms, offers resources and promotes processes. Furthermore, in these "middle lands" you can find the species that live in the two different environments, therefore greater biodiversity.

Margins can also be fences, roads and paths, walls, all elements of passage where actions and functions cross. In permaculture design you can take advantage of margins, by creating and increasing them in favour of a particular productivity.

Holmgren's principles

12. Creatively use and respond to changes

"Vision is not seeing things as they are, but as they will be"

The world is changing at an alarmingly exponential pace and humankind lacks the capacity to predict what the world will look like in 20 years. Geopolitics, governance, food production, energy, transportation are all elements that could change radically in the future. The currently very-real threat/reality of a global health pandemic is both worrying and painful.

However, as Permaculture designers, we must be prepared to see **opportunitie**s around every corner. Permaculture is the ultimate sustainability check which aims to regenerate natural ecosystems and human culture.

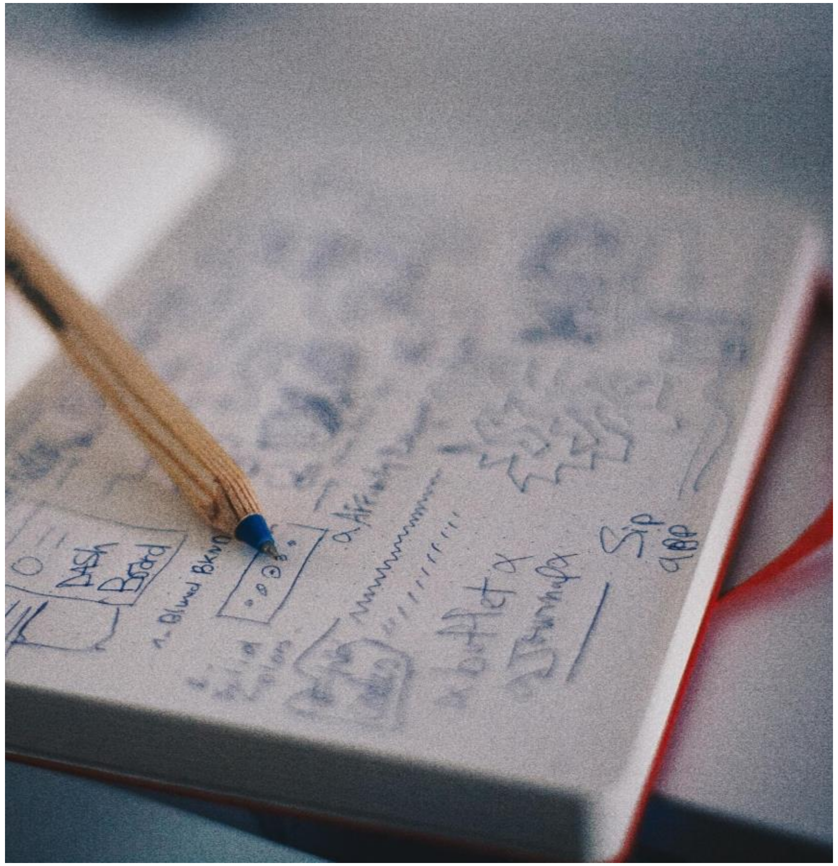
To achieve this as a Permaculture designer one needs thorough **observation** and **analysis skills**, to understand contemporary socio-ecological, economic, political and law structures, paired with a broad technical vocabulary and community leadership skills.

This principle is all about **flexibility** and **adaptation** as a pathway to resilience, both in **anticipating situations** and **planning ahead** for them (damming floodable areas or building firebreaks in fire-prone areas) or trying to creatively navigate unforeseen situations.

Application: Design Principles

Some practical additional principles can be applied when it comes to designing a practical system. These are all application of the aforementioned principles and are listed as follows:

1. Observe and Replicate Natural Patterns
2. Relative Location
3. Each element performs many functions
4. Each important function is supported by many elements
5. Efficient energy planning
6. Accelerating Succession and Evolution
7. Using Biological Resources
8. Use Guilds
9. Energy recycling
10. Work with Nature, not against it
11. The Problem is the Solution, Everything Works both ways
12. Make the Least Change for the Greatest Effect
13. Work Where it Counts
14. Small-Scale Intensive Systems
15. Everything Gardens

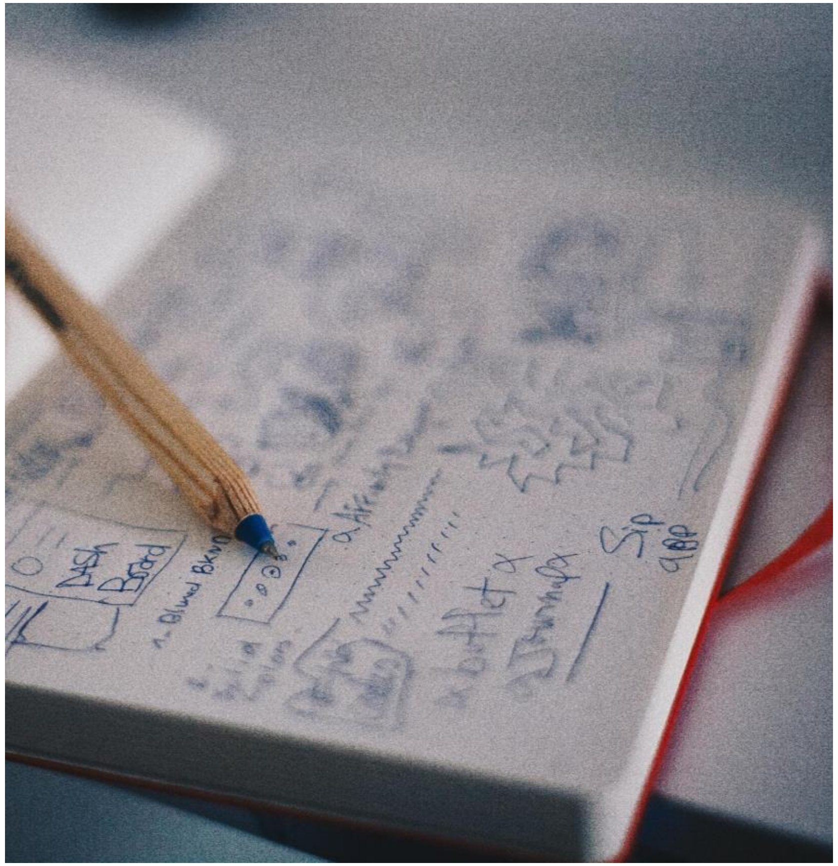


1. Observe and replicate natural patterns

Back to Application: Design Principles

Use protracted and thoughtful observation rather than prolonged and thoughtless action. Observe the site and its elements in all seasons. Design for specific sites, clients, and cultures.

Observation is the starting point of each permaculture design process. Pattern understanding is a strategic design approach to be fostered to maximize the application of working and functional solutions.



2a. Relative Location

[Back to Application: Design Principles]

Place the elements of your design in ways that create useful relationships and time-saving connections among all parts. The number of connections among elements creates a healthy, diverse ecosystem, not the number of elements.

In this principle, every ***element*** **(separate component in a design)** is placed in relationship to another so that they assist each other.

In Permaculture our primary concern is the relationship between things, and how they interact, rather than with the things themselves.

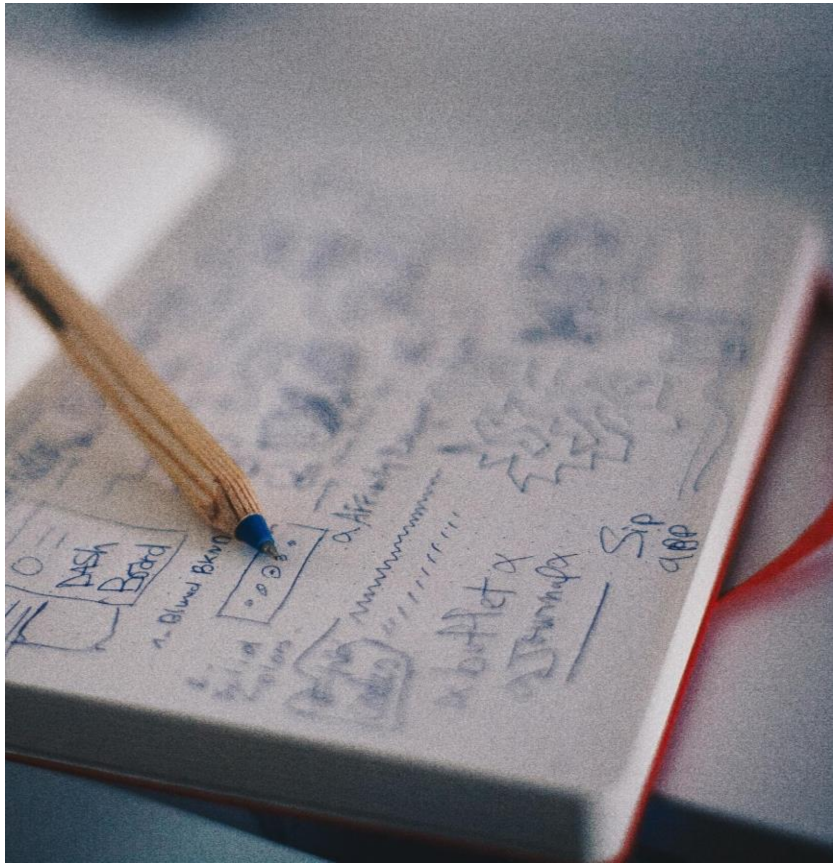
So, in Permaculture design, we focus on the **connection between things**, and by understanding the nature of the elements, and how they benefit each other, we can determine the optimum location for them.

All elements have inputs and outputs, and they can have many of these. Through the correct placement of elements, we can create a relationship where the outputs of one element feed into the inputs of another element in our design.

To know what an element's inputs and outputs are, we have to understand its nature, and when we have done this, we can determine the relative location where the element is best placed in our design.

In our designs, it is important to remember **that 'elements' do not just include the things we add, but also existing structures**. These include trees and buildings, as well as the 'real elements' of nature such as sun, wind, rain, and various earth features such as the soil type, slope/gradient, banks, gullies, waterways, hills, mountains and so forth.

In summary, we can optimise our designs using the Relative Location principle by locating design element near other ones so that their inputs and outputs flow into one another, or where they interact with another element to bring about the desired effect.



2b. Relative Location

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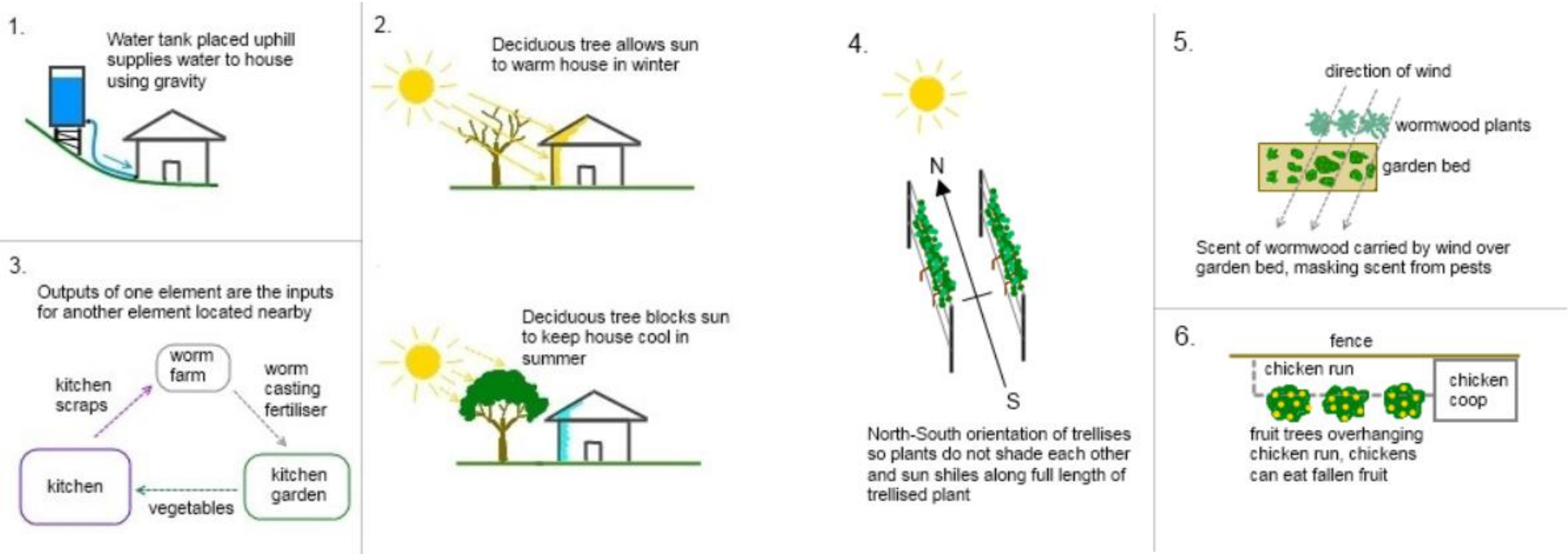

3. Each element performs many functions

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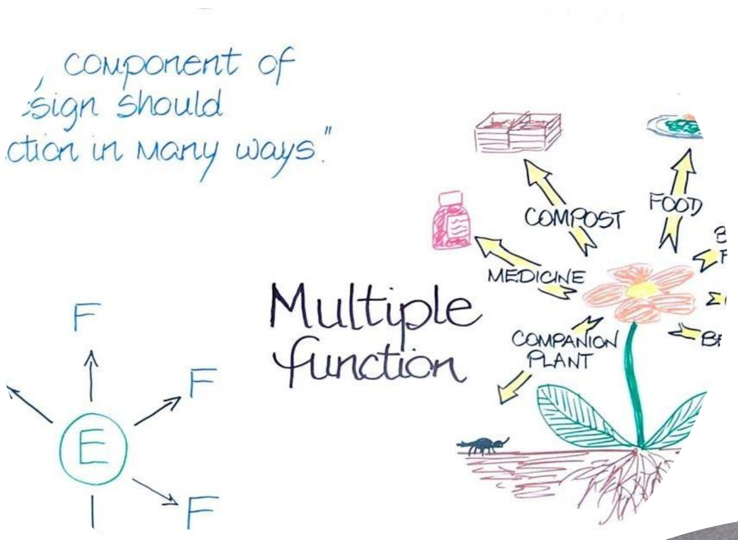
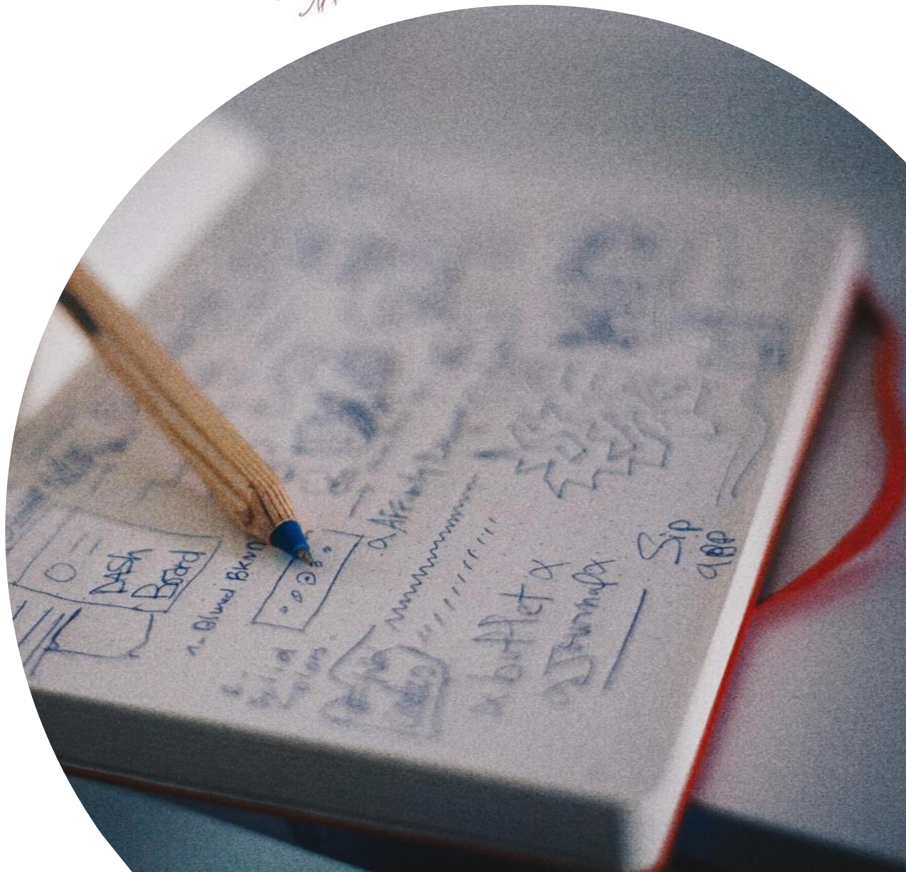


To maximise the efficiency of a design, **every element (component) is selected and located with the intention that it serves as many functions as possible**.

We can only do this when we fully recognise all the properties of an element, and when this element is a plant or animal, we must have a thorough knowledge of this organism. This includes its needs, outputs, attributes, the optimum conditions, and the range that it can tolerate, and so forth.

One way to do this is to perform a '**functional analysis**' to identify an element's needs, products, behaviours and intrinsic characteristics.

Choose and place each element in a design to perform as many functions as possible. Beneficial connections between diverse components create a stable whole.



4. Each important function is supported by many elements

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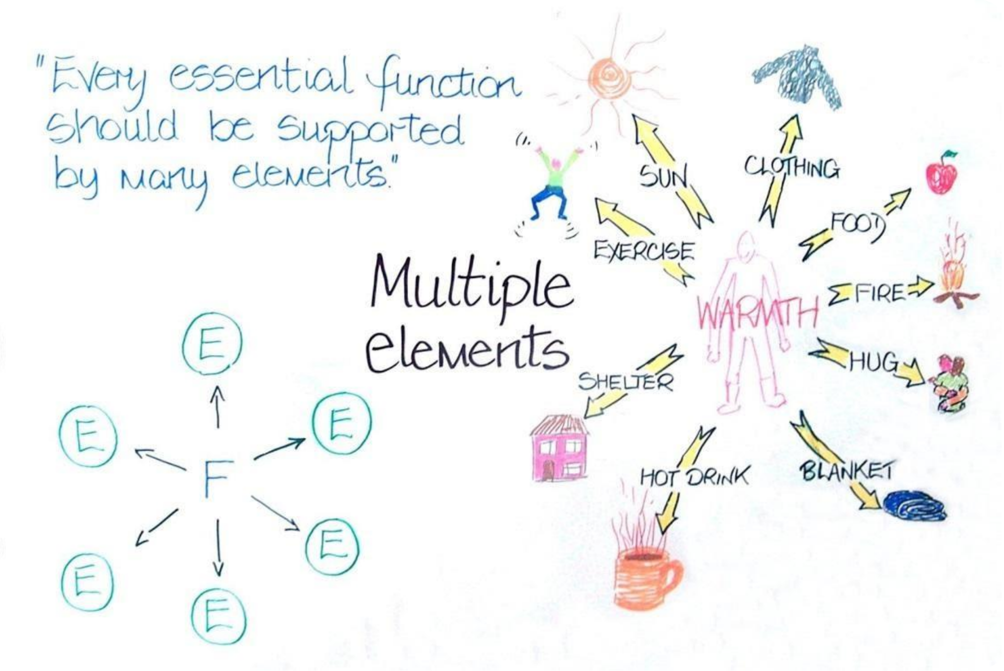

The key focuses of this principle are to:

- **Identify** which functions in the design are critical – such as water, food, energy, fire protection, and
- **Ensure** that these critical functions are supported in two or more ways

Firstly, the whole point of identifying which functions are critical is so that they are adequately addressed in the design. While this may seem like common sense, if this point is missed, the consequences can be disastrous to say the least. By formally addressing this step, we **create a checklist** of what we need to pay important attention to, so nothing is accidentally left out.

One of the largest flaws in a design would be to not address critical elements on which the success of the design depends. Secondly, the reason for ensuring that critical functions are supported in two or more ways is essentially that of resilience.

A resilient design is one where **the operation of critical functions continues** even if any of the elements were to break down. By building multiple systems to support one function, we eliminate any weak links in the design. **There is no single point of failure**, so our system has a higher chance of continuing to run should any unforeseen circumstances arise. Use multiple methods to achieve important functions and to create synergies. Redundancy protects when one or more elements fail.

5. Efficient energy planning

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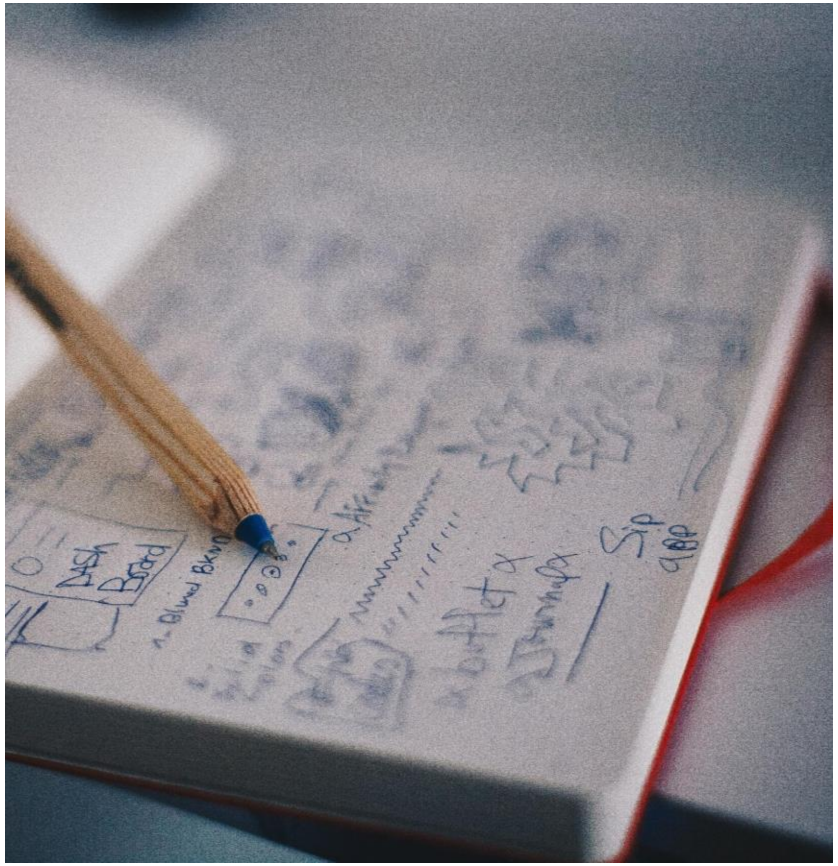
Make **the least change for the greatest effect**. Understand the system you are working with well enough to find its "leverage points" and intervene where the least work accomplishes the most change.

The design principle is concerned with planning the placement of elements in the design, such as trees and plants, animals, structures and buildings, to make to most efficient use of energy.

Efficient energy planning can be broken down to the following three categories further described in this manual:

- **Zone Planning**
- **Sector Planning**
- **Slope**



6a. Accelerating succession and evolution

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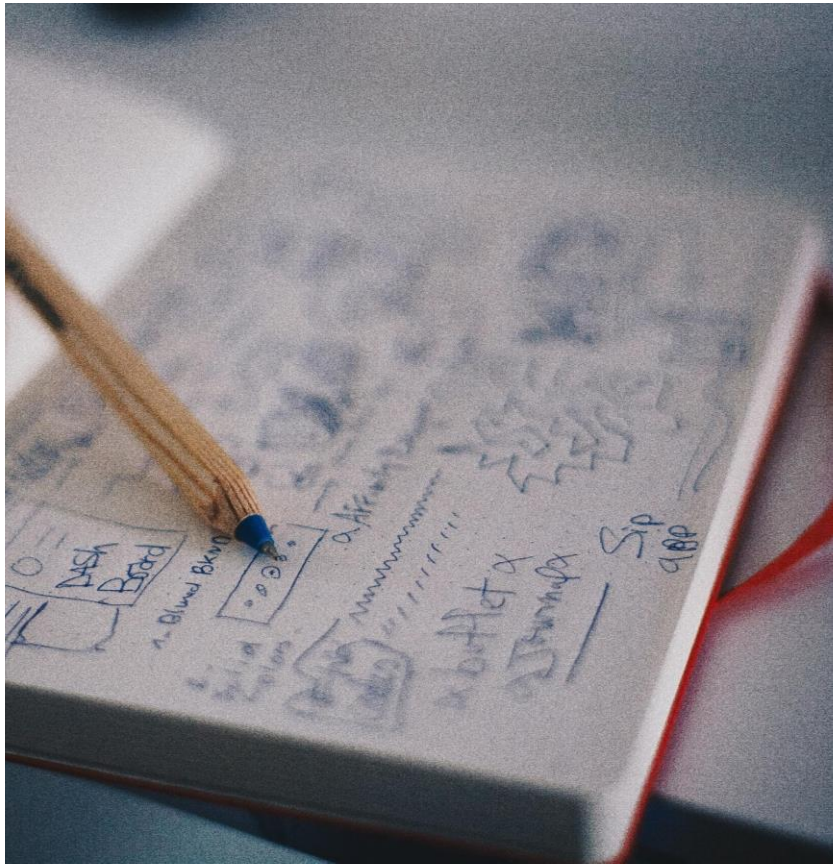
Living systems usually advance from immaturity to maturity. Mature ecosystems are more diverse and productive than young ones.

An empty field left undisturbed for long enough will inevitably turn into a forest, given enough time. Nature will fill empty, barren or disturbed ground with plants which quickly stabilise and build the soil, to prepare the ground for progressively larger plants, until the area is filled with trees, and many layers of understory plants beneath them. This process is called Forest Succession, and with this design principle, we aim to **assist Nature's efforts to accelerate this process**, so instead of waiting 50-150 years for a forest to develop for example, we can assist in the effort and create a climax forest in around 10 years instead.



Forest systems can be designed to produce food if we construct them using edible plant species, and they can produce other useful resources such as timber, fibres, dyes and medicines. In addition, what makes them special is that they are living ecosystems, and therefore support great biodiversity, they provide a home to a wide range of flora and fauna, which all comes together to create a balanced, natural, pest and weed free system.

Conventional agricultural systems try to keep the ground at the weed stage (annual plant stage) of forest succession by expending (wasting!) huge amount of energy in an attempt to try to reverse Nature's processes. The digging, weeding, spraying, and clearing never ends in an attempt to halt the natural process of forest succession.

Instead of trying to fight nature and pulling in the opposite direction to the natural flow in a futile tug of war, we can instead push in the same direction together and get to the same destination faster – a mature forest.

6b. Accelerating succession and evolution

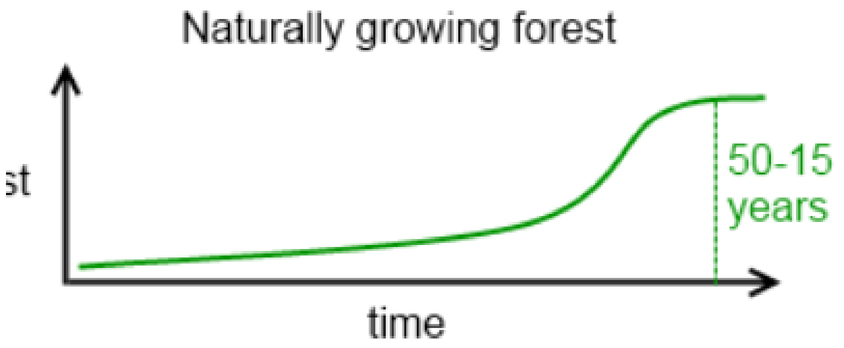
Back to Application: Design Principles

Normally, forests take a long time to establish themselves as they go through the successive stages of forest progression to reach the final climax forest stage. The height of the forest increases quite slowly at the earlier stages, and then shoots up at a faster rate once trees become established and start growing to the maximum canopy height.

By planting in all the layers of a forest at the same time, we can instantly create the multi-tiered structure and we don't have to wait for each step to be completed before the next one can commence. This way, we can speed up the process of forest succession immensely and create an established forest in no time at all.

There are a variety of ways in which we can accelerate the forest succession process and assist Nature to establish a forest system quicker than would naturally happen:

- **Using existing plants to build soil**
- **Introducing only hardy plants initially**
- **Raising the levels of organic matter in the soil artificially**
- **Substituting the plants of the forest succession stages with useful species of our choice**



7. Using biological resources

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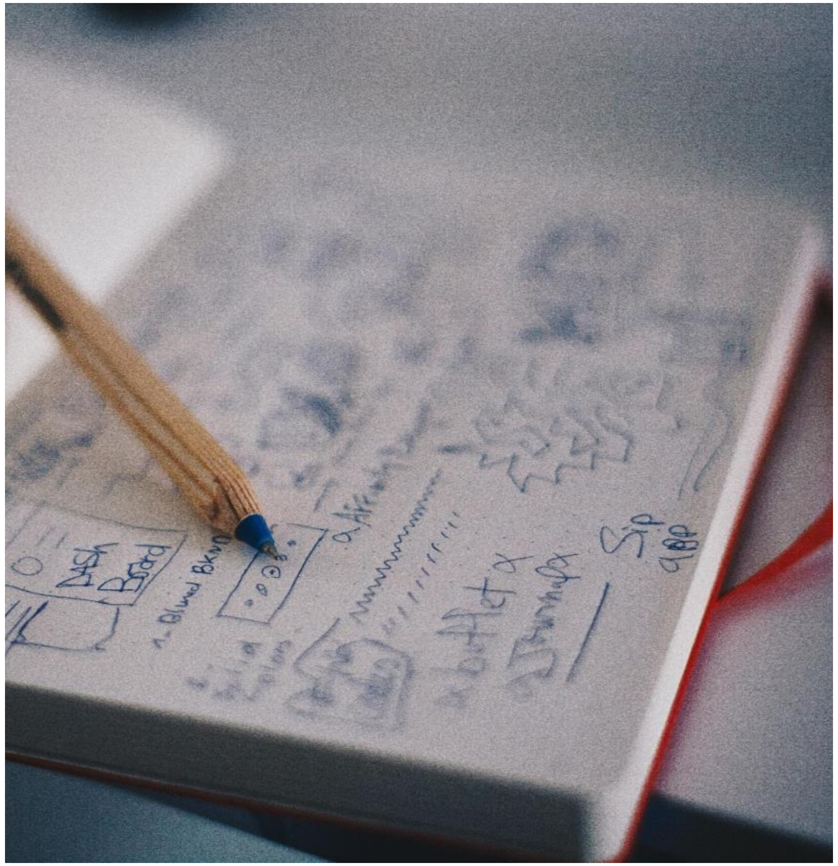
Use biological and renewable resources. Renewable resources reproduce and build up over time. Furthermore, they store energy, assist yield, and interact with other elements. Wherever we can use a plant or animal to perform a certain function in our designs, then this is our preferred approach.

For example, we can use livestock to keep grass short rather than using a lawnmower or use plants that attract beneficial predatory insects to control pests rather than using toxic chemical pesticides.

It is critical to plan the use of biological resources early in the design process. You will need to figure out which biological resources you wish to utilise on the site, and what your strategy will be to manage them. These biological resources will form the very basis of your energy recycling systems, and as a result, determine how sustainable your design will be.

It is important to point out at the beginning of this discussion, that even though we are favouring natural resources over less energy efficient non biological resources, we do not exclude the use of non-biological resources if:

- They are used only at the beginning of a permaculture design implementation to help create lasting biological systems (*if our soil is so depleted that it cannot support any plant growth, we can responsibly use a chemical fertilizer at the beginning to get our green manure plants growing, to build soil fertility. The fertile soil will be a lasting biological system*), OR
- They are used only at the beginning of a permaculture design implementation to build long-term physical infrastructure (*we can use non-renewable fossil fuels to power earthmoving equipment, which we can use to build permanent physical infrastructure, such as dams and swales (contour trenches) for water harvesting and storage, and roads for access*).



8. Use guilds

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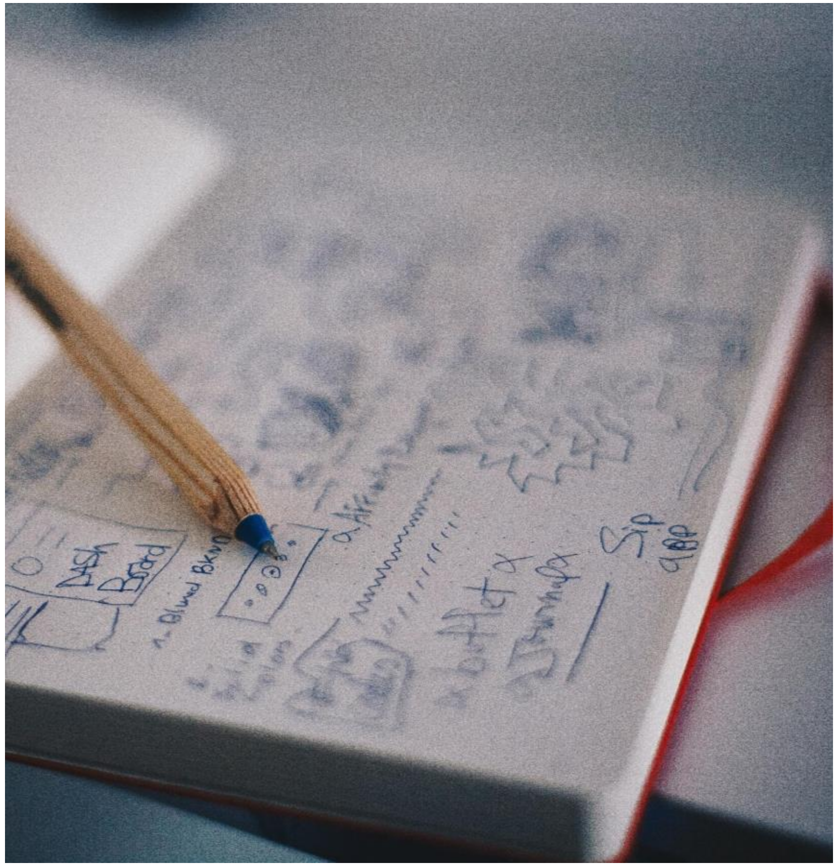
Learn and use the beneficial interaction between species.
See this section on Guilds for further information.



9. Energy recycling

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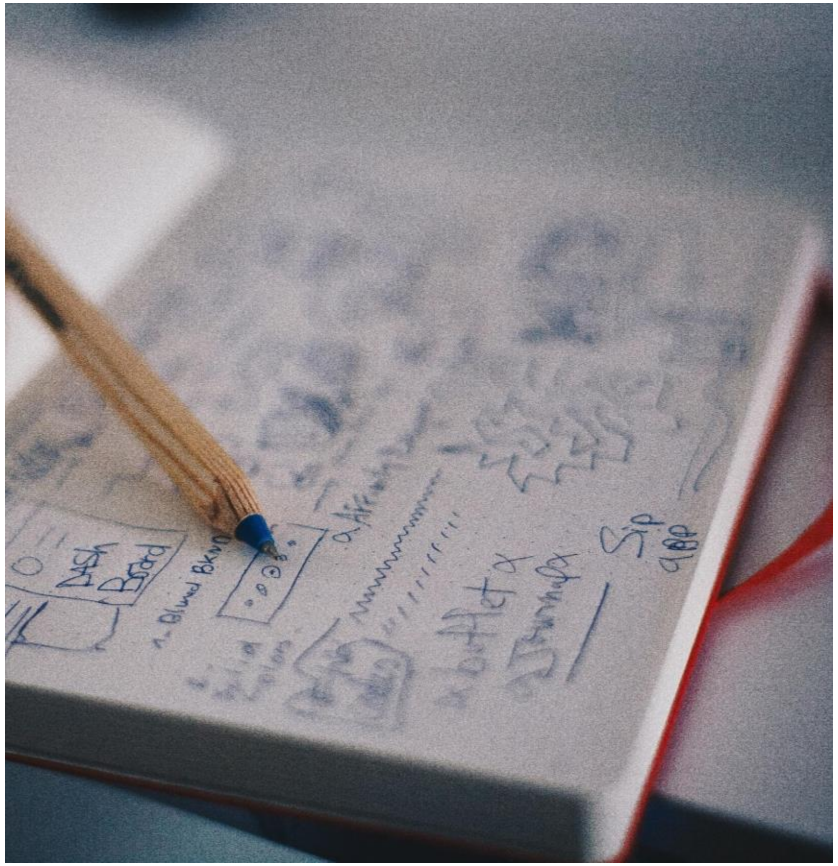

In nature, when energy is cycled, living systems grow. For example, when leaves fall from deciduous trees in autumn, they decompose, providing nutrients and an energy source to microbes, insects and other plants. If additional leaves are blown in by the wind from another location, they too will be added to the resources in this location and the living systems will grow even further.

In our Permaculture designs, we seek to capture energy to increase the growth of our living systems, and set in place cycles, which will perpetuate life.

The strategy here is to take energies flowing through a site and to divert them into 'cycles' to allow them to be utilised to ultimately increase the available energy on the site.

In energy cycling, we **recycle the energies** present on the site that would otherwise flow out of the system, and we **capture and store incoming energies** coming onto our site from external sources

Examples:

- *Fallen leaves are gathered to be used for mulch or compost*
- *Kitchen scraps and waste are used to make compost or feed worms in a worm farm*
- *Domestic grey water is directed into the garden to provide water and nutrient to trees*
- *Green manure crops are grown and cut down when they begin to flower, and are then dug into the soil to enrich it and add organic matter*
- *Animal manure is composted and used as a fertiliser, or used to produce biogas, which can serve as a source of fuel*
- *Rainwater is captured and stored at an elevated position such as a hillside so it does not require energy to pump it to a downhill location where it is needed*

10. Work with nature, not against it

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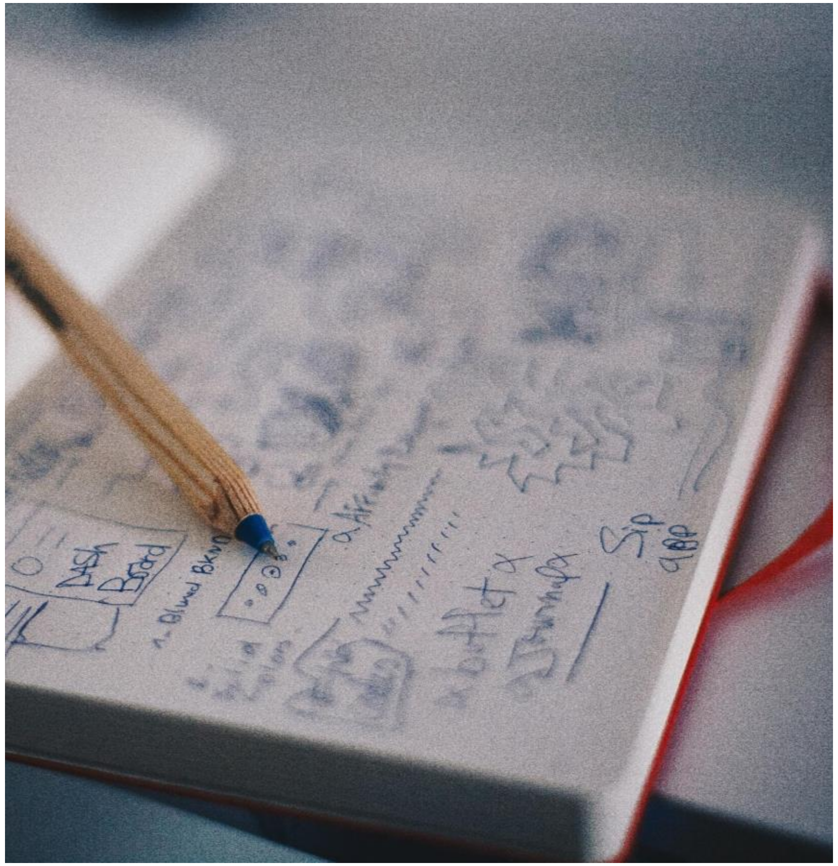
Work with nature rather than against the natural elements, forces, pressures, agencies, and evolutions, so that we assist rather than hinder natural developments.



11. The problem is the solution; everything works both ways

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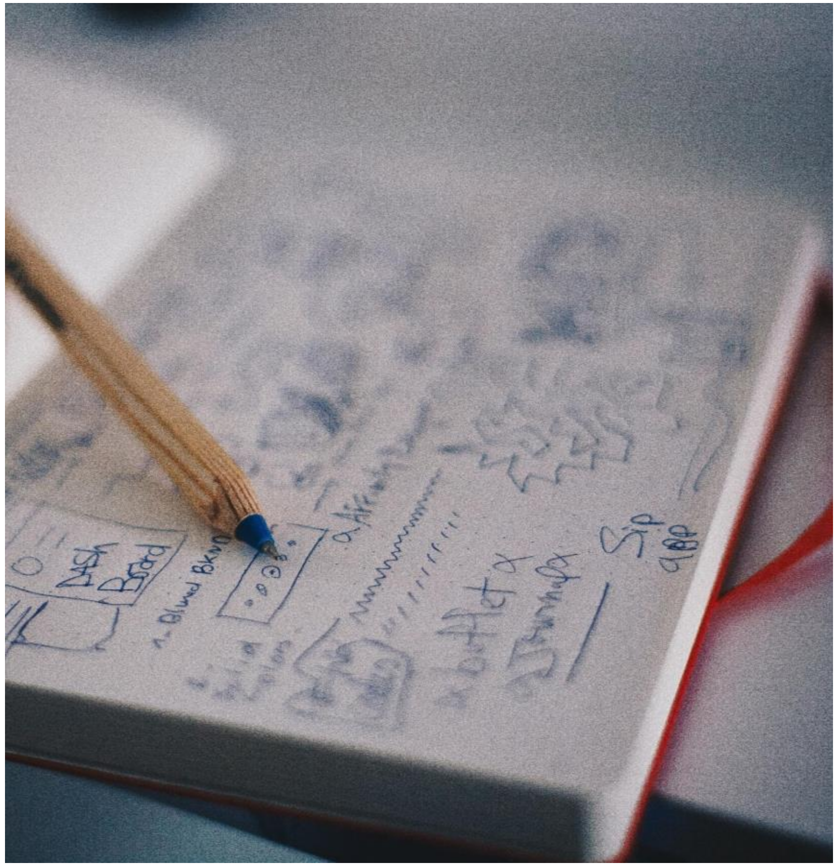
One of the most liberating aspects of permaculture is **looking at the problem as the solution**. By taking a different approach, we can use a perceived obstacle as a positive attribute instead.

For example, if we have a cold wind blowing across our land, how do we use its strength and cooling properties to our advantage in any design? Do we have a duck deficiency rather than a slug problem? Constantly damp piece of land? It can be transformed into a bog garden.

Everything can be a positive resource; it is just up to us to work out how we use it. Conversely, don't waste time, money or energy trying to force something into being something that nature never intended for it to be!



12. Make the least change for the greatest effect

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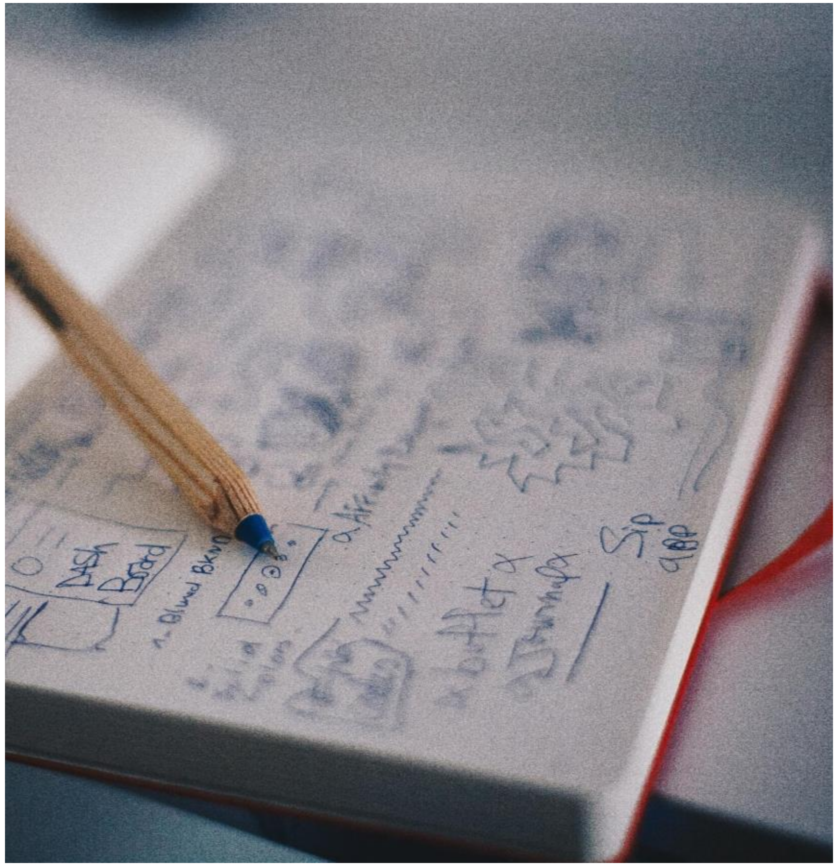
Make the least change for the greatest possible effect.

Small changes meet with less resistance than huge overhauls. I cannot afford to retrofit my flat and moving is a big upheaval that I am not ready for yet. So, I can start by draught proofing using old materials I have at home: pillows, unused itchy blankets, for example.

If I want to cut down on food packaging and eat more locally, I could grow salad on my windowsill, it would also cost me a lot less.



13. Work where it counts

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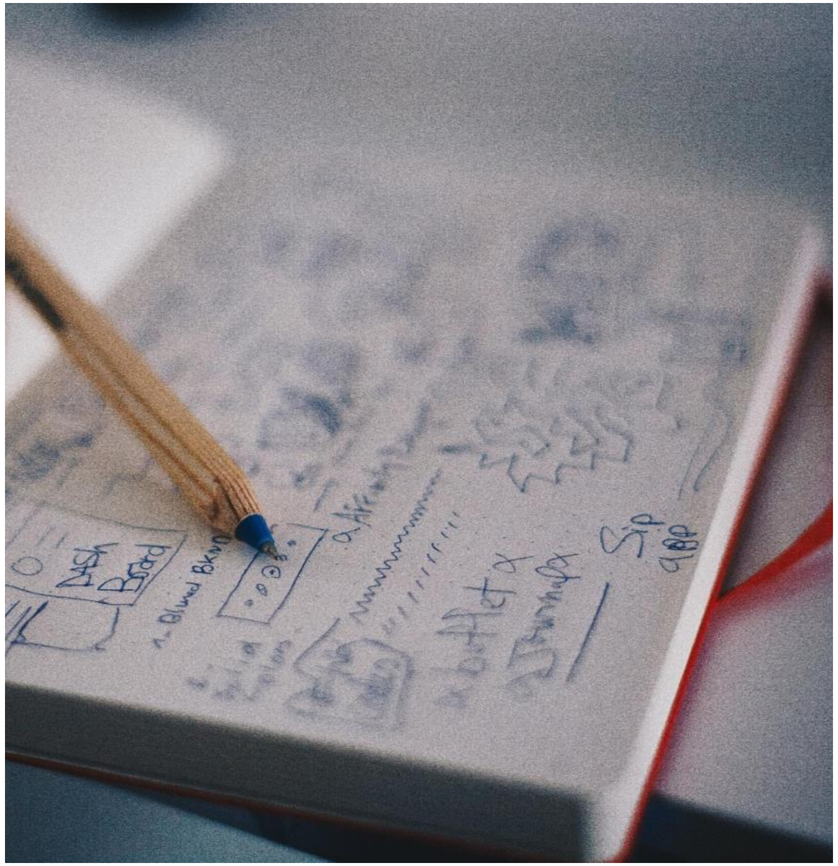
Before starting any activity, an evaluation of the **balance between cost and benefit** shall be performed. A **priority scale** should suggest then what is strictly required and what is nice to have.

Everyone has probably experienced having a limited amount of energy, budget, time during the development of any project.

The proper usage and allocation of resources is a requirement for any successful project.



14a. Small-scale intensive systems

Back to Application: Design Principles

In Permaculture, we design and build small-scale systems because they can be managed with **less resources**, which makes them very energy efficient.

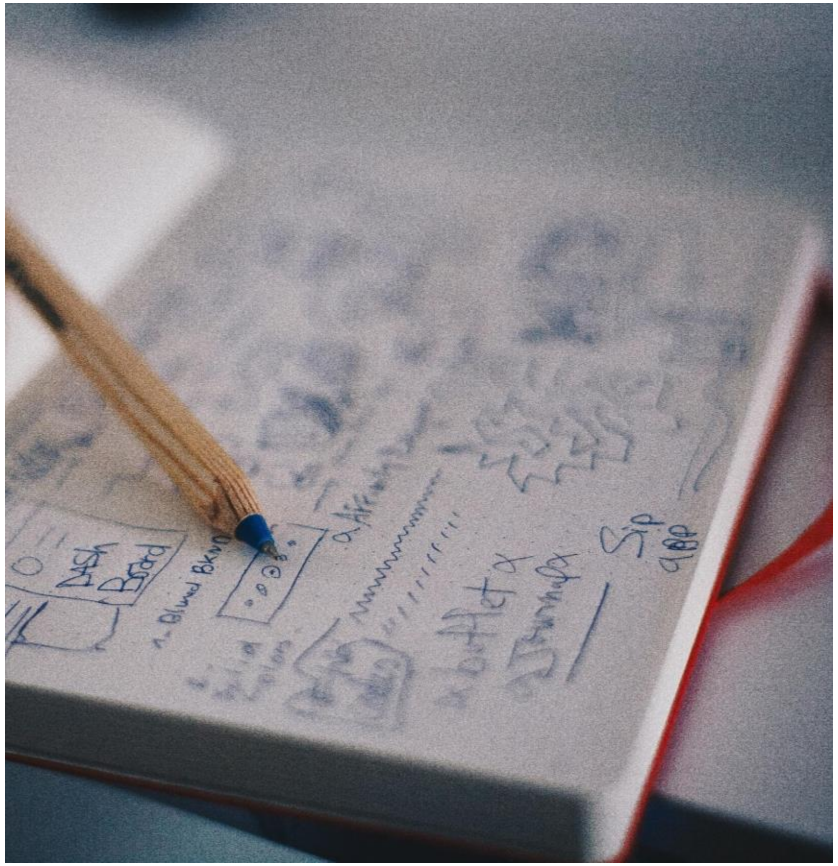
We also construct these systems as intensive systems to obtain the **maximum productivity** from these smaller manageable spaces.

Where possible, these systems are scaled so they can be managed with **human labour** and **simple hand tools**. Such systems use very little energy and can provide a very high-energy return on the energy invested.

Typically, in systems utilising human labour, such as peasant farming, one person can produce enough food to support 8-10 people, so the ratio of energy we produce to the energy we use is as high as 10:1. In these small scale systems, we don't just use human labour though, we can also use animals too, and where absolutely necessary we can use light machinery that uses moderate amounts of fuel, such as a small tractor.

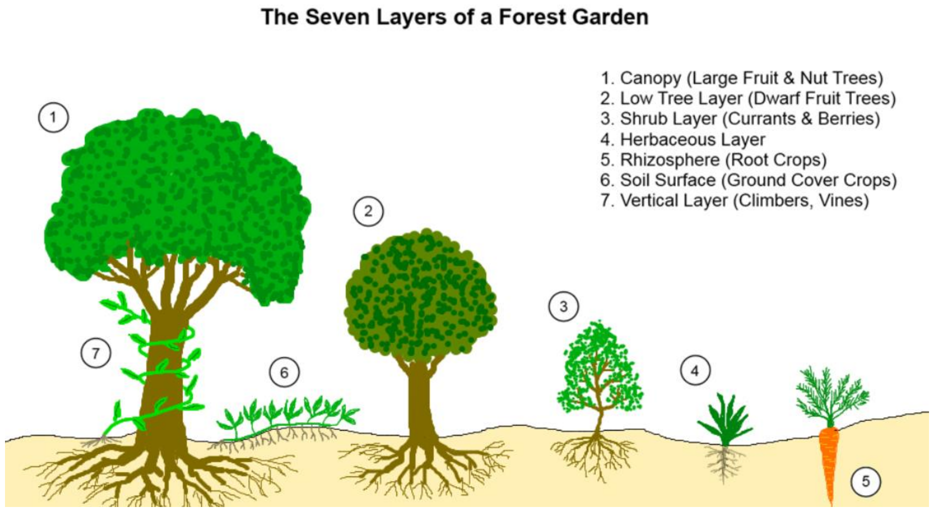
Obviously, acre for acre, a small farm utilising human labour, animals, and possibly light machinery is going to be far more energy efficient than hundreds of acres of commercial farmland employing heavy machinery, from where the food must be transported over vast distances and stored in cold storage.

The Permaculture small-scale intensive systems described so far might sound fairly similar to peasant farming systems or small-scale agriculture at this point, but this is where the similarity ends. Some of these differences are looked at in the next page, which distinguish Permaculture systems from the other systems, and the benefits these differences provide.



14b. Small-scale intensive systems

[Back to Application: Design Principles](#)



Plant Stacking – stacking in vertical spaces

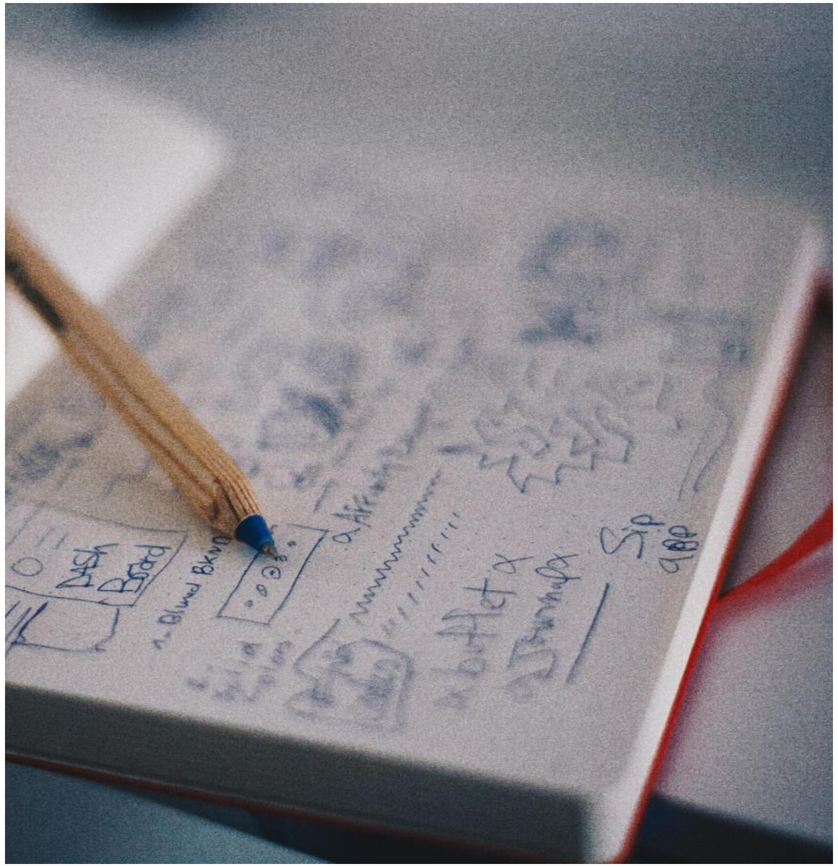
In a forest, Nature grows plants in a highly optimised pattern, utilising multiple layers and making the most of both horizontal and vertical spaces. A forest typically is comprised of seven layers, and in Permaculture we design food forests in the same way:

15. Everything gardens

Back to Application: Design Principles

A bird may collect small sticks, twigs, mosses and grass to construct a nest. It may eat insects and grubs; it may also eat berries, digest the fleshy fruit and excrete the seed. It drops feathers, gives off heat, it sings, it perches in trees on branches, it may scratch or peck at wood or the ground. It lays eggs and raises offspring.

All these have an effect on the greater environment; in a gardening sense - moving biomass and thus tidying the forest floor amasses biomass, removes pests from plants and turns them into nitrogen fertiliser. Furthermore, it collects seeds and distributes them, contributes biomass to the system and converts energy from one form to another to create soil fertility. Some further advantages include reducing and contributing to decomposition, contributing to the chorus of nature, and to the weathering and the breakdown of materials, while at the same time nurturing favourable conditions for subsequent generations.



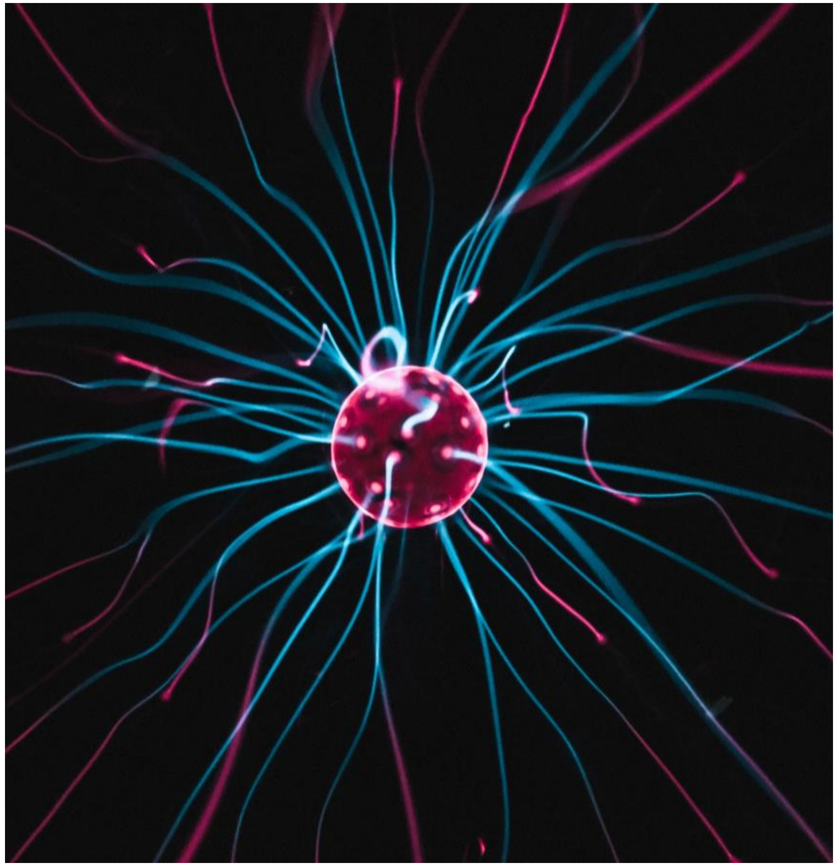
System science principles

Systems science is an **interdisciplinary field** that studies the nature of systems (from simple to complex) in nature, society, cognition, engineering, technology and science itself. To systems scientists, the world can be understood as a **system of systems**. The field aims to develop interdisciplinary foundations that are applicable in a variety of areas, such as psychology, biology, medicine, communication, business management, technology, computer science, engineering, and social sciences.

The primitive aims of science are to explore and denote knowledge about the structures and functions of nature. Systems science is a discipline that studies the structures, mechanisms, behaviours, principles, properties, theories, and formal models of abstract systems and their applications in concrete systems in engineering and societies.

Systems are widely needed because the physical and/or cognitive power of an individual component or a person is always insufficient to carry out a task or solving a problem. The systems philosophy is an important and the most general scientific philosophy that intends to treat everything as a system where it perceives that a system always belongs to other supersystem(s) and contains more subsystems.

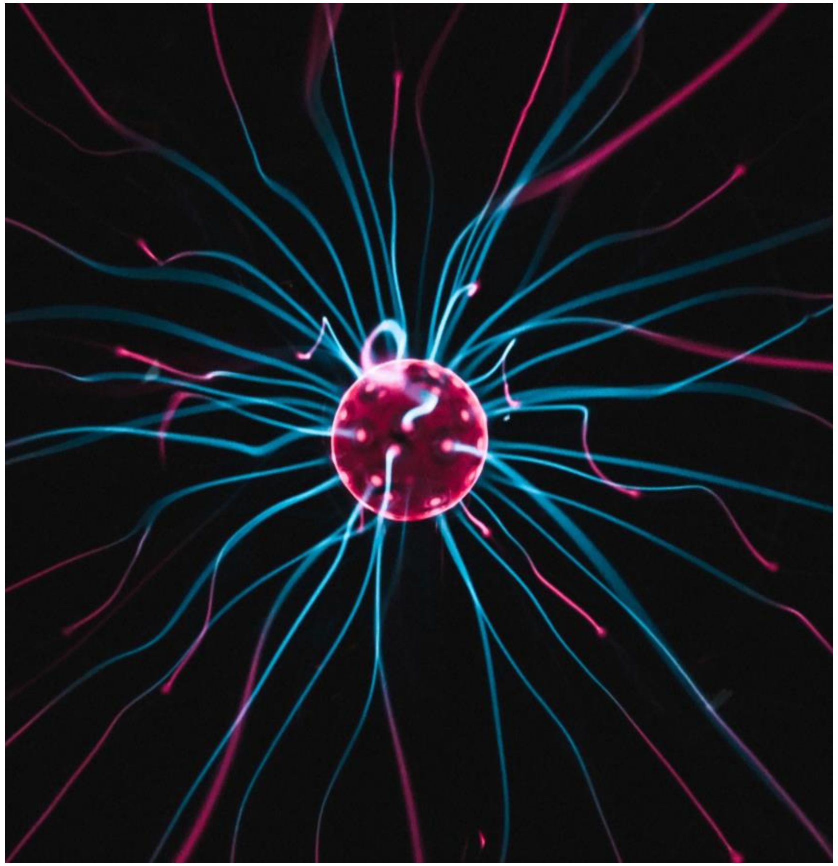
System science will be further developed in Volume 5.



System science principles

The systems science principles are provided below:

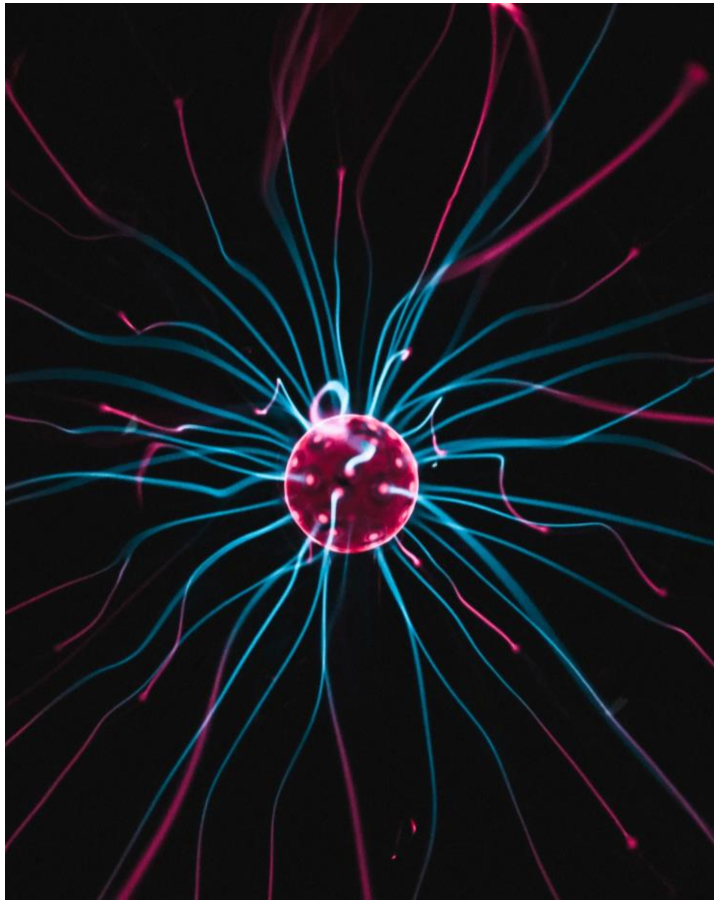
- "Systemness" – the world is composed of systems of systems
- Systems are organized in structural and functional hierarchies
- Systems can be represented as abstract networks of relations between components
- Systems are dynamic processes on one or more-time scales
- Systems exhibit various kinds and levels of complexity
- Auto-Organization is a dynamic process of making and breaking interconnections
- Systems can encode knowledge, receive and send information and learn
- Systems develop internal regulations to achieve stability
- Systems can contain models of other systems or of themselves
- Systems can be understood (a corollary of #9) – Science as the building of models
- Systems can be improved (a corollary of #6) – Evolutionary process that can be used to discover new aspects



System science principles

Systems Science Strategies are shared below:

- Observe models of specific systems, e.g. biological or social systems
- Use analytical methods to find commonalities on how systems function and evolve
- Develop languages that can describe all systems regardless of specific domains
- Develop general principles that provide explanations regardless of the details
- Develop mathematical descriptions that can be used to discover new aspects



Chapter 3: Regenerative Agriculture & Permaculture Core Principles & Tenets

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Regenerative Agriculture

Regenerative Agriculture builds upon the Ecological Standard and introduces a supplementary set of good practices for the continued evolution of the soil's natural fertility, the growth of biodiversity and animal welfare.

Its new objectives: Soil Carbon Sequestration, Increasing the quality of life of agricultural workers, ethical commerce & investments, tackle issues such as Carbon Emissions and include solutions for social and ethical concerns.

Regenerative Organic Certified™ = + CO_2 + GLOBAL ANIMAL PARTNERSHIP + FAIRTRADE

Regenerative Agriculture Principles

Permaculture and **Regenerative Systems** are based on an assembly-set of coherent practices conceived to simultaneously fulfill several functions:

- Soil Regeneration & Environmental Protection
- Economical Productivity & Profitability
- Human Well-Being & Positive Social Impact

Regenerative Agriculture improves upon the foundation of the Ecological Standard, which is mainly concerned with product quality, and imposes a set of supplementary ethical & quality standards concerning:

- Farm Investments, Acquisitions & Waste Management
- Production and Distribution Chains
- Soil Health & Fertility
- Animal Rights & Welfare
- Farmers' Quality of Life

The Vision of Regenerative Agriculture

A worldwide network of regenerative farms and enterprises which share an ethical system of food production and soil care with a visibly positive impact on the environment, society and economy which determine a vibrant culture and a responsible society.

Regenerative Enterprises are businesses which create and make available for society one or more of eight different forms of capital: financial, material, intellectual, social, cultural, experiential, living and spiritual. Businesses in any locality interact as enterprise ecologies, specialising in producing different forms of capital and redistributing these in line with the "Fair Share" ethic so that, for example, a highly financially productive enterprise might redirect fiscal surpluses to other regenerative living, cultural or other capitals.

See: Roland, E. C. & Landua, G. (2013). *Regenerative Enterprise: Optimizing for Multi-Capital Abundance*. E-Book v1.0.

From this, the concept of *Regenerative Capitalism* was developed, a global macro-economic model that seeks to be productive of all eight forms of capital, insofar as each contributes to human and planetary flourishing.

See: Fullerton, J. - Regenerative Capitalism (2015). *How Universal Principles and Patterns will shape our new economy.* Capital Institute.

Regenerative Agriculture Strategic Objectives

1. **Maximization of Production per cultivated unit** (ex. Growing in protected spaces, Polycultures, Season extension, Intensive Spacings, Using succession etc.)
2. **Regeneration of the Soil's Natural Fertility** (ex. Carbon Farming, Cover Crops, Minimal & No-Till, On-site Composting & Incorporation of Soil Amendments, Growing the Soil Food Web etc.)
3. **Increasing Work Efficiency** ("act according to plan" - holistic & strategic management & planning, using lean, scale-appropriate *Appropriate Technology* & workflows etc.)
4. **Increasing Quality of Life** (ex. Respecting the rights of agricultural & farm workers, Ergonomic & Safe production processes, Decent Wages, Creating a Farming Community, Celebration, Integration of the Social aspect etc.)
5. **Saving Time and Energy** (ex. Lean Farming, Reducing Waste & Simplified Workflows, Multifunctional Infrastructure, Automation of processes such as Irrigation, Ventilation etc.)
6. **Increasing farm value** (Water Harvesting, Growing Perennial Plants, Using Alternative Energy, Developing Complementary Enterprises etc.)
7. **Ethical Commerce & Investments** (Zero-Waste, Reduction of Inputs, Ethical Financing, Sliding-Scale product pricing etc.)

Regenerative Agriculture Decision-Making Matrix

- Ultimately, Regenerative Agriculture is a decision-making matrix comprised of strategies, techniques, design considerations from various branches of science & management
- It is primarily based on how nature & societies function

Regenerative Agriculture Tenets

1. Mimicking Ecosystem processes

- Nature functions in wholes and all of its organisms are highly interconnected in the complex and vulnerable web of life. We can apply this humble attitude to whatever action we take in our design and application on the farm and in our lives. We can even, if our imagination is strong enough, go as far as to apply nature’s patterning to our social systems and business structure.
- Everything is inspired from and governed by nature and its unpredictability. Hence, if we disregard it as the core ruleset, we will be fighting a losing battle, meaning that we will be doing more work, spending more money, time, resources etc. than we need to.
- The principles of Ecological Design are an invitation to observe, learn, gain insights, then apply: take a step back, look at how the natural processes work, integrate them into what we are trying to achieve and perhaps rely on Nature’s Way to accomplish our objectives.
- If we are to have an effective, efficient, productive and successful activity or farm we need to shave off a few seconds or steps out of every step of the workflow. If Nature can do that for us, why not let it?

Regenerative Agriculture Tenets

2. Locally managed inputs and outputs

- Permaculture, Agroecology and Regenerative Agriculture are based, as much as possible, around accessing local inputs and outputting products in the adjacent local community so that we do not perpetuate the trend of spending unsustainable amounts of energy in the form of gasoline and money to transport goods to an unreasonable place just for the sake of profit.
- In Nature, wastes from one enterprise are almost always resources for another, and this is very evident in a diversified farm: Winter Animal Bedding can be integrated into Annual Cropping Beds, Vegetable Scraps become Poultry Feed and Nitrogen-Rich Manure when processed by animals.
- There's an old adage: "*don't let anything off the farm that can't walk or fly off on its own*".
- Think of the farm as a battery, the more matter comes in via input and begins to flow in highly diversified relationship the more energy the battery have to power its processes

Regenerative Agriculture Tenets

3. Reduced fossil fuels, financial and technological inputs

- Conventional modern agriculture's approach to trying to solve the climate challenge is to increasingly use technology as a leverage point to deal with biological issues, and this is where small, human-scale farms using Appropriate Technological solutions can begin to position themselves and lead the way towards practicing, researching, scaling and sharing appropriate solutions.
- While not at the same scale of size, small-scale farms can achieve much higher efficiency per land unit through **intensive, holistic, integrated management**.
- By designing integrated, multifunctional systems we can work at lower costs with lower initial investments while producing competitive, high value, high quality products
- The Technological Innovation factor in the Appropriate Technology world has opened up immense potential for boosting human-scale productivity and enabling the rise of micro industries, 'Do it Yourself' (DIY) Construction & even tool fabrication.
- Novel & Creative ways of accessing and managing land make it even more possible for young prospective farmers to successfully implement & manage regenerative enterprises.

Regenerative Agriculture Tenets

4. Mobile and scalable infrastructure

- Investment costs, legal considerations and securing equity in land and farm infrastructure are all major barriers in the way of the advent of an easier entry into the field of regenerative agriculture.
- Lean Regenerative Farms are built with multifunctional, portable and scalable infrastructure because they allow for lower start-up costs along with flexibility in management, decision-making and recovery.
- Mobile, Scalable infrastructure permits quick implementation of any enterprise and allows for a simpler approach to the apparently daunting task of farming
- Chicken Tractors, Layer Trailers on wheels, Caterpillar Tunnels, Trailer Houses are only some of the mobile structures used on Regenerative Farms

Regenerative Agriculture Tenets

5. For the benefit of all

- For the Regenerative Lifestyle to persist, such farms need to be turning a decent profit which enables enterprise development and a decent life for the farmers, the customers need to be returning full of satisfaction about the value and quality of the products and the landscape needs to keep regenerating.
- Permaculture's Economic, Social and Ecological Ethics are the Philosophy of Life on which all decisions are made.
- Managing to solve problems, eroding topsoil, relying on Government subsidies and herbicide use, among others, is not sustainable technologically or bearable ethically and the cost of humanity's present rollercoaster ride is increasingly being externalized to future generations who have not consented to this inheritance.

Regenerative Agriculture Tenets

6. Regenerative Agriculture Education

- Europe is feeling the consequences of an aging population of farmers and of the insufficient number of young people getting into the agricultural sector. According to the EUROSTAT, the interest for agricultural entrepreneurship is higher in young people from the urban environment in comparison to young people in the rural environment.
- For young farmers, starting a business in the agricultural sector means facing risks and obstacles: limited access to land and high prices of land, lack of capital for investment, the pressure of bank loans, all of this in the context in which the young farmers have no practical experience in managing a farm, nor the technical competence. In fact, the lack of experience, complexity, obstacles and high risks determine many of the potential young farmers to not become farming entrepreneurs
- **Regenerative farms make an excellent choice for the practical, residential, educational, demonstration and productive ecological food hubs of the future**. Learning the craft of a regenerative farmer while being fully immersed in farm operations is the fastest, most effective way of mastering it to a level where the apprentice can rise to the level of manager.

Regenerative Agriculture Tenets

7. Access to Land

- In Europe, the amount of land destined for local, agroecological & regenerative farming is declining as a result of urban, industrial, residential & infrastructure development.
- Competition for land use is also growing between farmers' food production and other uses (timber, biofuels, fibres etc. As a result, farmland is becoming more concentrated in large, intensive farms while small farms are disappearing, despite the fact that they are the cornerstone of European and world food security, sovereignty and the key to maintaining a lively countryside. They also remain the best places to grow and provide quality local food, practice an ethical livelihood, preserve the tradition and regenerate the natural environment.
- The retirement of an ageing population of farmers and increasing difficulties in finding young entrants to replace them may result in further abandonment of rural areas, degradation of environments and urbanization
- For these reasons, and more, we need a broader evolution of national and EU policies & regulations on land use & management, support & mentoring schemes for young entrants into the agricultural sector, moreso for those who apply regenerative practices

Regenerative Agriculture Tenets

8. Community Land Ownership

- In a world where the real-estate market is becoming more and more exclusive and competitive and prices shift proportionally to a high-risk market, individual ownership, except for some exceptional cases, seems to be something from the past
- Co-Ownership & Community-Owned Enterprise is the next evolutionary step in equity, housing & agricultural property management

CASE STUDY

ACCESSTOLAND.EU PORTAL

- https://www.accesstoland.eu/index.php
- A portal containing European Networks of Grass-Roots Organizations securing land for Agro-Ecological farming with 4 main pillars of activity:
  - Preserving Land
  - Securing land for Agro-Ecology
  - Supporting a New Generation of Regenerative Farmers
  - Managing land as commons
- If you and a group of friends & partners with to set up a similar enterprise, a commonly-owned and ran regenerative farm, regenerative micro-industry or ecological mindful community you can check out this guide: https://www.accesstoland.eu/IMG/pdf/beginners_kit_19_05_20_fn.pdf

Regenerative Agriculture & Permaculture Strategies

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Agro-Forestry Patterns

- Agro-Forestry is a perennial intercropping system, trees and shrubs are integrated with annual crops. They can be established on arable land and in forests, and can also include animals
- In Southern Europe, agroforestry systems combining animals and trees are more common. There are traditional systems combining oak trees and pigs, sheep and olives, orchards and chickens.
- In Northern Europe there are many other kinds of alley cropping, with trees for firewood and cereals in between.
- Agro-Forestry Systems will always yield diverse, steady crops for the local community and are very climate-resilient, unlike annual plants
- Farm Forestry is an important element of agricultural design. yet it is totally missing from the conventional farming landscape
- Can be implemented on Ridges, in Valleys, on land not suitable to row-cropping / annual agriculture
- Agroforestry is vitally important for the future of agriculture because
  - Iit brings the Ecological Restoration aspect in Agriculture.
  - Builds Fertile Soil and Adds Fertility to the Landscape, producing and recycling its own nutrients,
  - Sequesters atmospheric CO_2 in the soil
  - Minimizes Erosion, Increases water retention
  - Creates habitat for biodiversity and nourishes many species (wild insects and birds)
- In terms of food security, the shift from annual to perennial crops is also important because annual plants are more vulnerable to climate disasters and weather extremes, while perennial plants become more and more resilient as time passes while providing many other benefits

Keyline

- The Keyline Pattern consists in planting Rows of trees on the contour lines of a field, spaced 12-28 Metres between the rows. The solar orientation and water distribution patterning are balanced out and a final design is made.
- Until they can grow steadily, trees are protected by guards & fencing. The strips may also have the function of windbreak and additional forage source. The rows of trees will also be planted with a diverse range of support plants.

Whatever we are farming and at whatever scale, nourishing microbes and building soil is our primary occupation.

Savannah

- Savannah systems are extremely productive and stable farming systems in grassland ecosystems, where the trees are spaced sufficiently far apart that the canopy does not close.
- Lone trees may prove to be relatively difficult to protect until establishment of the savannah. It is ideal to plant various mutually beneficial understory support plants in guilds around them, supporting the growth of fungi and to prevent compaction and over-accumulation of nutrients, which can lead to premature death.
- The Open canopy means that the soil level receives almost full solar exposure, which enables the accelerated growth of the grassland, row crops, shrubs, for the benefit of animals & farmers

Orchards

- A standard orchard's weeding and bottom pruning needs can be fulfilled with the help of holistically grazed sheep, chicken, geese or rabbits. There is often room in between the tree rows or on the row itself for additional cropping and the introduction of annual plants.
- Ideally, trees are protected and planted with guilds of compatible understory species, creating a web of life support in the grassland ecosystem.
- Specific species can be selected for extra functions, such as more fruit production, habitat, N-Fixation, wildlife attraction, etc.

Riparian Buffer

- A Riparian Buffer is a vegetated protective zone surrounding a stream, river or watercourse, which shades and partially protects the aquatic area from the impact of adjacent land uses while filtering water entering the system and physically holding the banks together.
- It is a very common conservation practice designed to increase water quality while decreasing its potential pollution.
- They can be permanently or occasionally fenced away from the access of grazing animals to keep them clean and in conservation status.

Windbreaks

- Wind disturbs both crop production and livestock and is a force to be reckoned with in the long-term. Even in a well-insulated house heat is lost through cold wind passing over the house and windbreaks should be planned for also in the design of human dwellings.
- Well-constructed shelterbelts can protect against wind for a distance of 10-20 times their height in horizontal distance. When it comes to designing the windbreak itself, one can factor in other functions in the species selection phase so that one will obtain multiple additional yields.

Avenue Plantings

- Avenue or Road Plantings are a great way to make use of a marginal and unproductive space by planting it to produce additional yields of timber, shelter or forage.
- Close-spaced timber trees (Oak, Chestnut) can be pruned to produce a straight central leader for future high-quality saw logs with which the next generations will be able to build their homes.

Timber Blocks

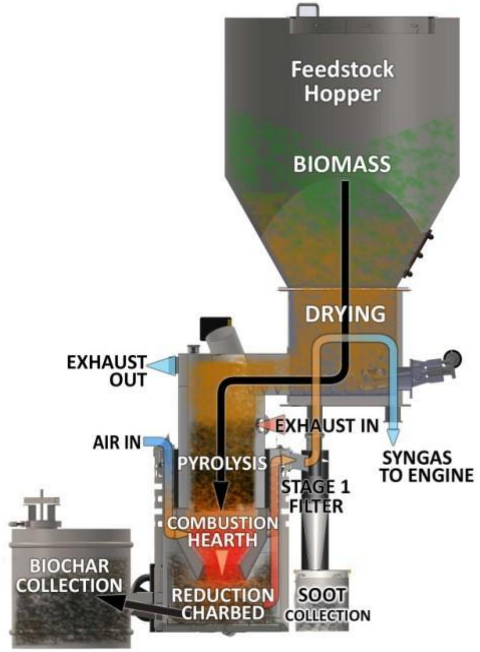
- Intensive Timber Blocks can protect and utilize exposed ridges and poor soils. Multiple species of mixed hardwoods are an important element in fluctuating global economic and weather patterns.
- Deciduous trees planted at the appropriate spacing into pasture have no detrimental effect on it and livestock for more than a decade, although forage production falls if trees exceed 35% canopy cover.
- This is another example of combining forestry and pasture enterprises to make better use of the land base.
- Timber blocks are an excellent way to preserve land with a productive end in mind: producing timber for the next generations while keeping the soil populated with roots and under a high canopy.

Forage

- Trees provide shade and shelter, if they can also have the additional function of producing animal fodder it is even better. For this to happen the trees must not be overgrazed so that they can maintain a rhythm of recovery that does not deplete them. It is important to minimize tree damage in the form of grazing, trampling and rubbing.
- This can be done through seasonal exclusion, strategically placing salt / mineral licks to encourage uniform livestock distribution etc.
- Grazing helps the trees with the grass competition and reduces the habitat for bark-gnawing rodents, including rabbits.

Biomass

- With the rapid development of turn-key wood gasification units, as well as recent developments in Jean Pain's wood-based compost heating systems, the overall importance of integrating woody agriculture into a farm has reached a new level.
- Field shelterbelts of coppiced biomass such as willow or hazel can become feedstock for wood chip boilers, substrate for edible fungi and animal bedding. By alternating the harvest of double rows, habitat and shelter elements are maintained continuously, even as harvests are made.
- Advances in gasification technologies provide potential power generation for small farms based around their own biomass supply.



No-Till; Minimal-Till

- "100% Ground Cover, 100% of the time"
- Bare soil is just asking for weeds
- Planting & Sowing in crop residues

Biointensive

Made popular by small-scale farmers like Curtis Stone, Eliot Coleman & Jean-Martin Fortier, it is a highly efficient, high nutrient input, small-scale, standardized organic “market gardening” cropping system with a very precise workflow, ultra-high density seeding rates, set of tools, techniques and strategies and even distribution model, which allows for the highly intensive and quick-turnover production of annual, short-cycle crops with the aim of distribution in the local food chain.

Holistic Management

Holistic Management was first developed over 40 years ago by Allan Savory, a Zimbabwean biologist, game ranger, politician, farmer, and rancher, who was searching for ways to save the beautiful savannah and its wildlife in southern Africa.

Through the work of Allan Savory & Holistic Management we now have the tools to clarify and consider the complexities we must navigate as regenerative farmers and land stewards & managers through the development of the **Holistic Context** for making decisions which ensures that they are **Socially & Culturally Sound, Economically Viable and Ecologically Regenerative**.

The philosophy of Holistic Management is in line with Permaculture's principle of integration, rather than segregation.

Clarity around the context in which one makes decisions makes the process of major decision-making smoother and clearer, which translates into a well-rooted long-term vision of the project under management, better management of people, no matter their culture & smoother operation in daily tasks on the farm.

- Ecosystem Processes: Understand the language of the land by paying attention to the soil surface
- Management Tools: Add the regenerative power of livestock to your toolbox
- Whole Under Management: Describe what you are managing
- Holistic Context: Describe what your life must be
- Filters: Use the seven testing questions to ensure decisions reflect your Holistic Context
- Feedback Loop: Monitor to stay on the right track
- Building Wealth Through Holistic Financial Planning: Create the annual Holistic Financial Plan to support your Holistic Context
- Holistic Planned Grazing and Monitoring: Get animals to the right place, at the right time, for the right reasons, with the right behaviour
- Holistic Land Planning: Develop infrastructure on large tracts of land
- Holistic Ecological Monitoring: Nurture the land you steward

Lean Farming

"All we are doing is looking at the timeline from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by removing the non-value-added wastes." - Taiichi Ohno, creator of the Toyota Production System

The approach & Basic Goal of Lean Farming is to "ruthlessly eliminate waste - anything the customer does not value - from your production system" and have "as few interruptions as possible in the flow of work."

Lean Farming is a way to get the job done: obtain customer satisfaction, a quality product & outcome in a reasonable time-frame while also having enough time to ensure the quality of life desired by the enterprise operator, which is something unfortunately not found in contemporary business entrepreneurial practices (agricultural or otherwise).

Ohno's way of viewing "lean" is to analyze **capacity**, the amount of product that can be produced in a given span of time, in the following equation:

"Capacity = Work + Waste".

On the contrary: bottlenecks, burnout, long hours, inability to take extended leave away from the enterprise often cause discomfort, feelings of dissatisfaction medical & psychological conditions and significantly lower the quality of life of people employed & managing enterprises. (agricultural or otherwise)

To enable a world of balanced life, work & results, our goal is to apply Permaculture's People Care Ethic (**see Ethics & Principles**) in such a way that it transcends and harmonizes our economic activity to our desired quality of life..

Thereby, we strive to identify, eliminate waste and reach 100% working potential, while applying Kanban (Matching Demand to Production Capacity) and Kaizen, (Continuous Improvement).

Lean Thinking Principles

In the book *Lean Thinking* James P. Womack and Daniel T. Jones define the lean approach as a set of 5 Principles:

- Identify & Precisely Specify Value
  a. Identify customers' needs & wants, extrapolate on what they might also need
  b. Do market research, interview, ask for feedback, ask "What would you do?"
  c. Be extremely client-oriented
- Find & Map the Value Stream while removing Waste
  a. Do value tracing: Where is the valuable product created on your farm?
  b. Plan thoroughly and stick to the timeline & management plan. Tweak. Start from seeds to depositing the cash in the bank.
- Make Value flow without interruptions
  a. Identify & eliminate waste ruthlessly
  b. Identify Bottlenecks
- Let the customer pull value from the producer
  a. Produce exactly what the customers want, in the amounts they want and when they want it.
  b. Let customers *"pull"* (guide the production)
- Seek perfection through continuous improvements
  a. Develop a farm culture of continuous improvement
  b. Achieve perfect flow: zero waste production

Lean Thinking - The 8 Wastes

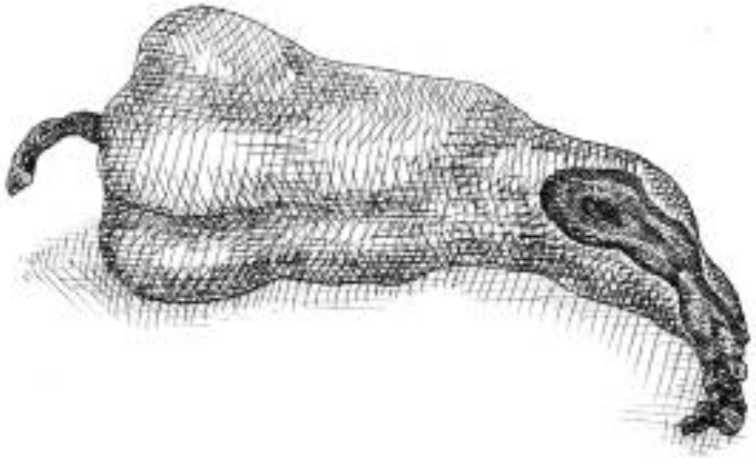
- **D**efects – Dead animals or ruined feeds
- **O**verproduction – Producing too much than what can be sold
- **W**aiting – Delays due to insufficient capacity
- **N**ot using talent – Idle time for laborers
- **T**ransportation – Unnecessary transfer of goods from one station to another
- **I**nventory – Overstock; Storing too many crops or even tools
- **M**otion – Looking for tools; Having too many steps in the process
- **E**xcess processing – Doing something unnecessary out of tradition; too much cleaning

Feeding the Soil Microbiology

- The Soil Food Web's primary producers are Plants, Algae, Lichens and certain groups of Bacteria which fix atmospheric carbon.
- The next trophic orders of soil organisms obtain their energy by consuming the primary producers and their waste products.
- By adding organic matter in our soil from and by introducing a planned grazing process to add manures and other animal waste products and disturbances we are, essentially, adding organic carbon sources as a source of food for the Soil Food Web.
- Nutrients are then converted through various digestion & transformation processes and made bioavailable to plants & other soil organisms.

Micronutrients

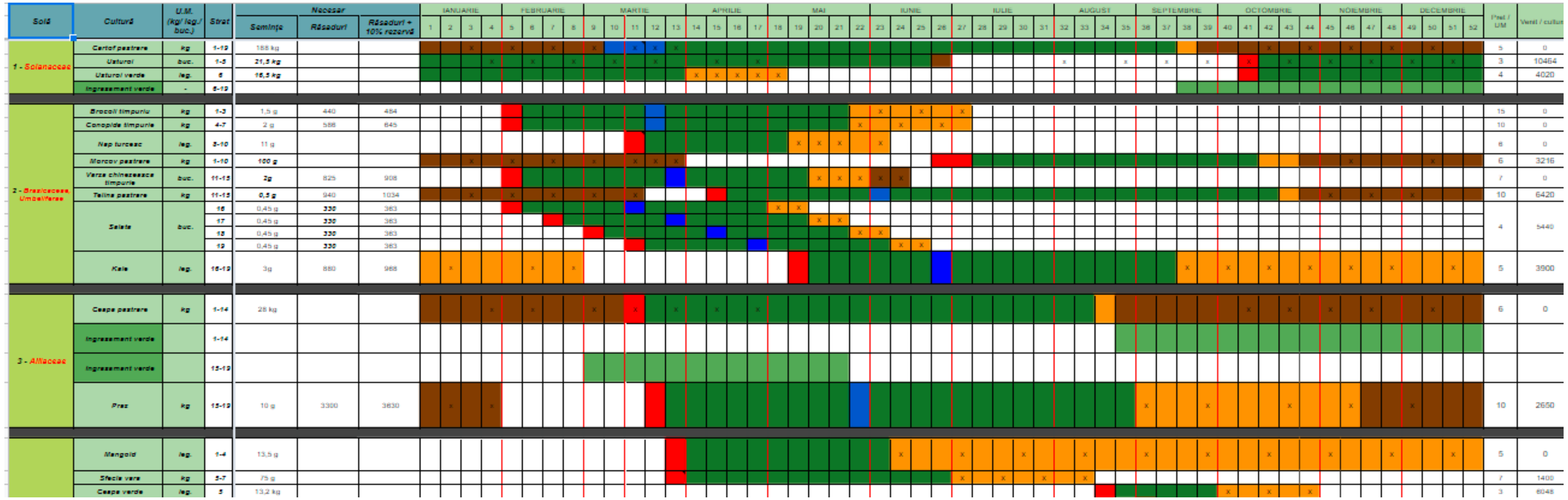
- Also known as trace elements, small quantities of *micro*nutrients are essential to crop growth.
- In most cases proper crop rotation, composting and mineral amendments should be enough to ward off micronutrient deficiencies.
- In some situations, this may not be the case and micronutrients such as Boron and Molybdenum may be lacking, which are insufficient to fulfill the needs of some heavy-feeding crops from the Cabbage family, in which case they are added to the crop directly through a foliar spray, in the optimal quantity, instead of trying to amend the soil.
- The Foliar spraying strategy saves time and feeds the crop. However, it does not solve the problem in the soil. Foliar sprays should be consciously used but there needs to also exist a long-term soil management plan which involves massive additions of diverse composts, which may contain the element that will correct any eventual deficiencies (seaweed etc.)



Blossom-end rot is a physiological disease that can lead to major crop losses. It occurs when the weather is warm and there is insufficient consistency of water intake by the plant. This in turn leads to a lack of calcium during the fruiting period. To prevent this disease, we systematically supplement our peppers with calcium during part of their growth cycle.

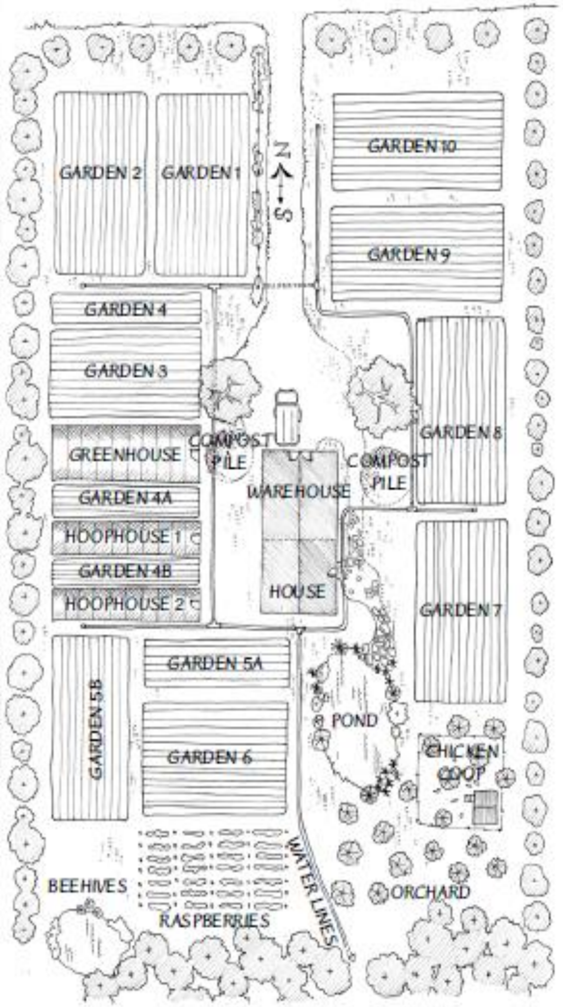
Crop Planning

- For the sake of soil fertility, plant health, the diversity of the products of a farm, a successful Regenerative Farmer must practice a crop rotation
- The two main advantages of practicing crop diversity and rotation are:
    - To allow the soil to produce more crops while maintaining its natural fertility by alternating crops with different requirements so that while a certain set of nutrients is in demand and in depletion, another set is being replenished. Usually, the crops are rotated taking into account the family they belong to (Brassicaceae, Fabaceae) or their nutrient requirements (heavy feeder / light feeder)
    - To eliminate insects and diseases and weeds which tend to appear and stabilize when one species in particular is continuously planted



Crop Planning

- In the Market Garden we practice crop rotations for the reasons above and more:
  - To be able to grow a large diversity of crops year-round
  - To have as many cropping cycles on a single bed, eliminating excess tillage operations and growing more product in less actual bed space than conventional agriculture
  - To allow plants with different root systems to penetrate the soil to various depths, improving its structure and mining it more efficiently for nutrients
  - Strategic weed management: using certain mulching techniques to prepare soil for the establishment of future crops



Appropriate Technology

Appropriate Technology means utilization of simple & efficient small scale and low impact technologies technologically and financially viable, a softer technology with a focus on ecology.

The *Appropriate Technology* sector is developing using *Open-Source* principles, creating the *Open-Source Appropriate Technology* movement. Designing OSAT solutions takes into account ecological, ethical, cultural, social, political and economical aspects of the communities which use them.

- Low production and maintenance costs
- Open-Source production, utilization and tweaking schematics
- Decentralization
- Increase of local autonomy & independence
- Increasing Energy Efficiency
- Decrease of Ecological Footprint

Appropriate Technology

The tools used in conventional agriculture heavily contribute worldwide to soil erosion and environmental degradation through monoculture, pesticide & herbicide use, methane gas production.

For agriculture to transition to a regenerative system there must be a wave of change that impacts all areas of farming.

Most farmers worldwide practice subsistence agriculture, which could become profitable small-scale agriculture with the right technology.

International Agricultural Industry innovates and develops products mainly destined for use in industrial large-scale agriculture, not in human-scale agriculture.
In Europe, small-scale tools & technologies are poorly represented on the market (the most important distributors worldwide are Johnny's Seeds - USA and Terrateck in France.)

Young farmers' access to information, innovative technology and tools at an accessible price could leverage the transition from s

Appropriate Technology

The utilization of OSAT solutions empowers the community's entrepreneurial spirit and creates alternatives to the utilization of large scale industrial solutions oriented strictly towards profit-oriented mass production (usually industrial and agricultural technology with a heavily negative environmental impact.)

In developed countries, Appropriate Technology has developed at the onset of the 1970s' energy crisis and aims to develop and disseminate functional, cheap, sustainable technologies which protect the environment and use renewable resources.

In developing countries, Appropriate Technology is seen as a solution for economic development and an easy way to achieve a technological transfer from the developed countries.

Regenerative Agriculture Techniques

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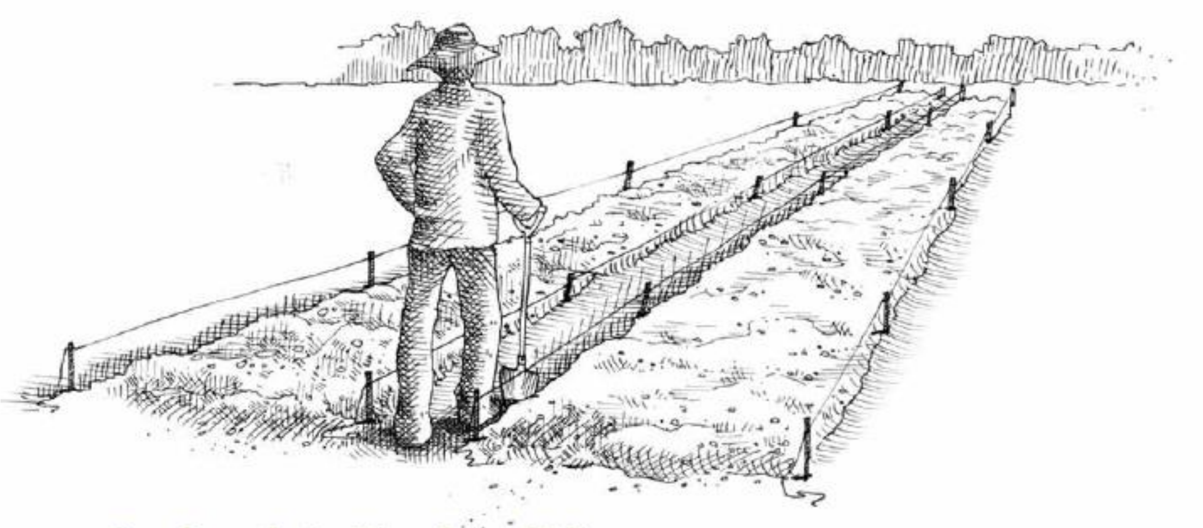
Permanent Raised Beds



Depending on the size of the garden, establishing permanent beds may take a few days or even weeks.

- Soil Building: All of the previous benefits, and especially using the same layout of beds and paths season after season allows organic amendments, microbiology and soil structure to thrive and not be wasted on paths or evaporated during aggressive and/or intensive cultivation practices.
- Soil warms faster in Spring: Being a few inches higher, the soil intercepts the sun's rays, heats up, allowing the production season to begin sooner, giving the producer a market advantage. The soil also dries faster if wet, allowing more versatile cultivation & production strategies
- Decreased soil compaction: In a permanent bed & alley system beds are never walked on, no heavy machinery is used. Loose soil structure and limited tillage allow the crop roots to dig deep in search of water, support and nutrients.
- Improved Drainage: Excess Water drains away from the crop, into the alleyway and permeates the root zone. The remaining runoff continues into drainage canals and water retention features The drainage features make sense for humid European springs and autumns

Cover Crops; Green Manure

- A popular mix is Oats, Vetch and Field Peas. The Legumes are mixed with Oats, to give them something to climb on as they grow.
- The best time to mix in a green manure is just before it flowers. At this stage the plant has stored its maximum nitrogen and will make the greatest contribution to soil fertility.

A flail mower will shred the plants into small pieces; it is an indispensable tool if you want to use cover crops in the market garden.

Cover Crops; Green Manure

- Cover Crops & Green Manure are grown to add nutrients & organic matter to the soil.
- They are mainly grasses and legumes which, at a particular moment in their lifecycle are mowed, plowed under and incorporated into the soil to increase its fertility
- Many of these Cover Crops are Nitrogen-Fixers, with the capacity to capture atmospheric Nitrogen and store it into the soil. When such a crop is incorporated, the degradation of plant material releases the nutrient and makes it bioavailable to the following crop.
- When cereals (Oats, Rye, Wheat etc.) are mixed with legumes (Alfalfa, Vetch, Beans etc.) the residues contain not only Nitrogen, but also Carbonaceous organic matter.
- Therefore, Green Manures can be considered amendments, just like Compost or Animal Manure
- Their Advantage is that the material is produced onsite and requires only seed, labour and processing.
- Their disadvantage is that they take up growing space that can be used to grow vegetable crops and they lock it up during their growth (6 weeks to a whole season) and 2 more weeks for the period required for the microorganisms to break down the green manure and make the Nitrogen bioavailable.
- If compared to making and spreading compost, Green Manures are an effective way to fertilize large surface.
- In the context of a biointensive market garden using Green Manures is far from ideal. Also, without a small-scale flail mower (BladeRunner) it is difficult to incorporate them into the soil.
- However, their other function, aside from being an excellent fertilizer is that of a Living Mulch

Cover Crops; Green Manure

- Taking into account the constraints of a small-scale farming enterprise, integrating cover crops & green manures into the crop rotations is done to provide a living mulch, fertilizer and to allow the soil to rest between heavy feeders.
- A popular mix is Oats, Vetch and Field Peas. The Legumes are mixed with Oats, to give them something to climb on as they grow.
- The best time to mix in a green manure is just before it flowers. At this stage the plant has stored its maximum nitrogen and will make the greatest contribution to soil fertility.
- Before flowering, the crop is still young and tender and will decompose easily, in time for the next crop to take over.
- Legumes do not fix atmospheric Nitrogen by themselves. The fixing is done by the *Rhizobium* bacteria, which forms nodules on the roots of the Leguminous plants to permit the exchanges to take place
- However, looking at the state of soil microbiology as it is related to contemporary soil management and tillage practices we can extrapolate that, to create the proper environment for these Nitrogen-Fixing bacteria to exist we need to, most easily, inoculate legume seeds with the proper rhizobia.
- The inoculum is available as a powder.

Cover Crops Used at Les Jardins de la Grelinette

WHITE CLOVER. We prefer white clover to red, which is cheaper but also less vigorous. White clover is slow to establish itself but very hardy. It is also difficult to get rid of once established. We mostly plant it at the edges of our gardens, where it adds nitrogen to the soil, survives the winters, and does not require regular mowing. Since the seeds are so fine, we mix it 50/50 with sand before broadcasting it. This ensures that the seeding is not too dense.
Seeding rate: 2.2 pounds/100 feet of bed (including 50% sand)

OATS AND LEGUMES. Our main catch crop is an oat-pea mix. It can be seeded very early in the spring, as soon as the snow melts. It adds a lot of nitrogen and biomass to the soil and is a great weed smotherer. In the fall, we like to replace the peas with common vetch. Either mix (oats and peas or oats and common vetch) requires eight weeks to grow before being turned under. We aim to seed this cover crop by September 1.
Seeding rate: 3.3 pounds/100 feet of bed, a mix of 60% peas or vetch and 40% oats

FALL RYE. Fall rye is very useful in providing plant cover for beds where late harvests have taken place. This species requires four to six weeks to fully develop and grows even in cold conditions. However, it is very hard to eliminate, and even after shredding, a simple pass with the rotary tiller is generally not enough to kill it. To get our fall rye growing before winter, we aim to seed in the first week of October. The plants come up again in the spring and produce lots of biomass by the end of May.
Seeding rate: 3.3 pounds/100 feet of bed

BUCKWHEAT. Buckwheat is useful for rapidly covering the soil and crowding out weeds. Since it goes to seed eight to ten weeks after being seeded, we take note to mow it before then. Because buckwheat is highly sensitive to frost, late August is our latest seeding date.
Seeding rate: 3.3 pounds/100 feet of bed

Cover Crops; Protecting the Soil

- Cover Crops are excellent for protecting the soil in the winter and are usually planted after the last crop rotation going into winter.
- Bare soil exposed to extreme weather will break down, degrade in structure and quality, especially in the winter months when there is no snow cover. Also, in the spring if the soil is not covered water runoff can cause nutrient leaching and erosion problems which decrease soil fertility.
- It is important to prepare the soil for winter by mulching with crop residues, covering with a tarp or planting a late cover crop to provide plant cover.
- Planting a Winter cover crop improves the soil tilth for the beginning of the next season.
- Ideally, the Winter Cover Crop should be planted at least 6 weeks before the first frost is expected so that the root system develops enough for the plant to grow throughout the cold fall and winter weather up to the spring.
- The other option is to sow a spring cover crop after the snow has melted and to mow down after 6-8 weeks, for starting the direct-seeded crops.
- Protective living mulch is seeded very densely so that it effectively covers the soil surface.

Cover Crops; Weed Suppression

- In Large-Scale Organic Vegetable Production farmers introduce Cover Crop Rotations over longer periods to actively direct the weed cycles of their fields.
- In Small-Scale High Rotation Market Gardening this technique would disrupt the profit margin, but the weed-suppressing properties of Cover Crops are used in certain beds that will, for certain reasons, be free for a long-enough period for the technique to have an effect
- Buckwheat is effective in mid-season to form a plant cover dense enough to suffocate weeds in approximately one month. Its flowers offer food for the bees, attract pollinators and its biomass increases biological activity in the soil once turned over
- Weed-Suppressing and Living Mulch Cover Crops are seeded at 5-10 the normal density so as to achieve an effective plant density

Cover Crops; Adding Organic Matter

- Incorporating green plants with delicate stems will leave very little stable organic matter in the soil after decomposition
- Very fibrous plants which resist decomposition must be used to leave organic matter in the soil,
- Densely seeding fall rye and sorghum-Sudan Grass Hybrids will markedly improve soil structure with their roots and produce large amounts of biomass.
- However, microorganisms use Nitrogen to power their decomposition action and to digest the fibrous green manures. This can, in fact, rob the soil & the plants of Nitrogen Cover Crops are sown using higher-density seeding rates
- The seeds are mixed into the soil with a quick & shallow pass with the rotary tiller or the wheel hoe
- Usually, soil moisture is good enough for proper seed germination. If not, a sprinkler line can be deployed to give it an initial watering-in.
- After it has grown to the proper incorporation age the crop must absolutely be shredded by a flail mower to a size suitable to be incorporated by the soil micro-organisms
- After shredding the crop, we can cover it with a black silage tarp and let the soil microbiology do the job of digesting and incorporating it or we can till it in with the rotary tiller.
- Common agricultural practices call for mixing in the material in the first 20cm of the soil. This is done with the tiller at the minimum speed so that the mixing of the material is done without breaking down the soil structure too much.
- Another option is to use the rotary plow to throw soil from the path on top of the shredded material.
- The least invasive option is to sprinkle compost and irrigate the shredded cover crop residues and cover them with a black tarp. However, when there is no time for it, the tillage option remains an effective strategy

Rapid Hot Compost

- 18-Day or Berkeley Compost is fast and easy to replicate.
- Materials are chopped to 1-4 cm lengths to create more surface area for them to contact each other and to break down easier. The harder or woodier the plant tissues are, the smaller they need to be divided to decompose rapidly.
- The Organic Material should have a starting Carbon:Nitrogen ratio of 30:1.
- Compost made of 25% Animal Manure, 45% Green Manure or Plant Material and 30% Woody Material is suited to bacterial piles to be used in the vegetable garden
- Compost made of 25% Animal Manure, 30% Green Manure or Plant Material and 45% Woody material is suited for a Fungal Compost to be used on woody shrubs & trees.
- When Green & Woody Organic Material is finely chopped, the Nitrogen in that material is more readily available to the microbes. The bacteria will "bloom", increasing its temperature and rapidly using up oxygen. To prevent the development of anaerobic conditions, compost with finely chopped material and regularly turn your compost.
- Carbonaceous material can be leaves, finely shredder cardboard, compost, sawdust, wood chips from pruning etc.
- Composting works best at a 50-60% moisture content. The chopped, mixed materials, when squeezed in the hand should clump and hold as a rough ball but should fall apart if rubbed A film of water should cover everything but not drip. Too much moisture will slow down decomposition and will smell. Too dry material will halt decomposition altogether
- The Compost pile's size should be minimum 1 to 1.5 m3 so that they have enough thermal mass as to prevent heat loss and still be manageable at a human-scale. Heat is a product of the respiration process of the millions of soil microorganisms in the process of breaking down the organic material.
- The compost pile needs to be turned regularly to prevent its overheating. During the first 4 days the pile will reach 55 degrees Celsius, during which human pathogens, weed seeds, plant pathogens and root feeding nematodes perish. Non-Organic Manures or material can be reclassified organic after such treatment.

Rapid Hot Compost

- After a few days the temperature reaches 60-65 degrees Celsius and the compost goes into overdrive, consuming oxygen faster than it is possible to be oxygenated naturally so the farmer needs to intervene and aerate it by turning the inside out and the outside in, so that all the material has the chance to reach the optimal point during the life of the pile
- A pile should never reach 70 degrees Celsius, and for measuring it a long-probed compost thermometer is very useful. After 70 degrees Celsius the beneficial microorganisms die and we aim to create an environment in which they should thrive
- Pile temperature and activity typically peaks at 6-9 days and then it begins to cool back down to ambient temperature
- A cover is necessary to keep rain out unwanted humidity, to prevent excess evaporation & drying and to reduce heat loss from the middle & top of the pile
- Observing the pile's temperature will guide turns
- Once a pile has been started, no extra materials are added, except in the case of major corrections (adding more sawdust to solve a humidity problem). No starters are needed as the microorganisms which perform the digestion already colonize all the organic material added to the pile.

A compost thermometer is not essential, but makes monitoring and managing compost much easier. Worthwhile if you are making regularly.

Rapid Hot Compost

- If the pile is too wet the organic material should be spread out for it to have room to dry for a while before re-making the pile
- If the Organic Material is too dry, spray with water evenly to increase the moisture level
- If the pile has not begun to heat up after a few days and the moisture levels are adequate it means that there is not enough nitrogen to jumpstart the heating process. Add a liquid source of organic matter high in nitrogen (Chicken Manure, Urine etc.) as you re-layer the pile
- If the organic material in the pile is shrinking or the temperature is becoming too high it means that the organic matter is decomposing too fast for it to become bound into the Carbonaceous materials and the will be a waste of Nitrogen which will be evaporated as Ammonia, signalled by a specific odour.
  To mitigate this process it is beneficial to add sawdust or another high carbon material
- White masses, similar to fungi, could appear in the pile and are a sign that oxygen levels have dropped and temperature has gone up. Anaerobic compost will result in lost nutrients and conditions which can favour the growth of Human Pathogens, such as E.coli Salmonella and Listeria.
- By keeping the Compost aerobic we are aiming to grow the microbiology that outcompetes the Pathogens. The similar process we are carrying out in our soil, by keeping it oxygenated and well-aerated. Therefore, we try not to walk on our vegetable beds, use heavy machinery to drive over it, over-graze etc.

Growing Fungi in Compost

- Upwards of half of the mass of a well-constructed & managed compost pile is predominantly bacteria, protozoa and nematodes. On the other hand, fungi are more fragile and slow-growing.
- To make a fungal-dominated compost tea wheat bran is used as a substrate. It is hydrated up to 60% and mixed with the finished compost at a ratio of 1 part Compost : 3 parts bran. The mixed preparation is then put into a warm and well ventilated environment for a few days, until the fine hyphae hairs are visible across the surface of the material.
- When Hyphae are visible the preparation is ready for inoculation of other materials or to be used for making compost tea.

Bran from the local mill is hydrated to around 60% humidity in a flat container approximately 70 x 40 cm.

Finished aerobic compost is mixed in at a ratio of 1 part compost to 3 parts moistened bran.

Once the ingredients have been thoroughly mixed the tray is moved to the floor of a polytunnel where it remains warm. Cover with cardboard.

After 3 or 4 days the surface of the material is covered with hyphae and the material can be used in compost tea preparation.

Actively Aerated Compost Tea; Bacterial

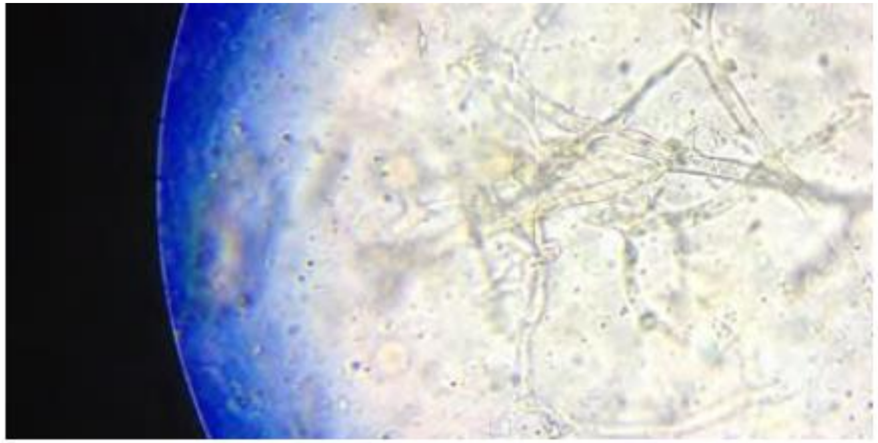
- 7 kg bacterial compost
- 500ml sugarcane molasses
- 250ml kelp extract
- 200ml liquid filtered plant extract or comfrey tea
- 4 tablespoons fish emulsion (fish emulsion is more beneficial as a bacterial food than a fungal food as it does not have the oils which help fungi grow)

The beginning of a tea; the surface will become thick with a healthy white foam indicating high levels of life.

Actively Aerated Compost Tea; Fungal

- The Fungal Inoculant for fungal teas comes from the compost, to which 500g more grams of rolled oats or bran are added and put in the compost “teabag”.
- The resulting “tea” is best used immediately so it is good to synchronize the end of production with the application. It is best applied as a foliar or soil drench in cloudy weather.
- The tea should be applied to both the top and bottom of leaves, stems and plant parts or sprayed directly into the topsoil. A mulch layer increases organism survival.
- Applications for preventing foliar diseases are suggested at 50L / ha every 2 weeks starting at 2 weeks before bud break and continuing until there are no more signs of the disease. Disease eradication is due to the tea microorganisms outcompeting the disease microorganisms.

- 9 kg fungal compost
- 500ml humic acids
- 250ml kelp extract
- 250ml Fish hydrolysate
- 500 g rolled oats or bran



A lot of fungal hyphae are brown, but may be transparent. Fungal hyphae have clear division nodes which are easily seen at 400X magnification.

Liquid Biofertilizer

- Making biofertilizer is an anaerobic process, through which nutrients, vitamins and hormones are extracted and chelated for quick absorption through the plants' stomata, when applied as a foliar spray.
- While most of the nutrients plants need will come through other ways, this foliar preparation can stimulate photosynthesis which will allow the plant to convert more sunlight into carbohydrate exudates which feed microorganisms in the soil. They help release more nutrients for the plant which can then produce even more sugars to feed the soil life.
- *Bacillus Subtilis* is a bacterium cultivated through this process which can help solubilise phosphorus and make it bioavailable in the soil

The delightful process of playing alchemist on the farm. Farm-ready low cost solutions exist for all our needs if we look for them.

Liquid Biofertilizer

- 200L drum with locking lid and an air lock
- 150L water (dechlorinated)
- 50L fresh cow manure
- 2L fresh raw milk
- 2L sugarcane molasses. Sugarcane molasses contains a wider spectrum of trace nutrients (too much will create alcohol that will kill microorganisms)
- 3kg Wood Ash (or Burnt bones)
- 500g fresh yeast or 25g dry yeast
- 1L Worm Castings
- 1L Kelp Extract
- 3-4 KG Rock Dust
- The manure is added first for practical reasons, The rest of the ingredients are mixed in a bucket together with the molasses and filled to the top with water. 15-20 cm of air space is left at the top to avoid air lock blockages once the fermentation begins
- The barrel is sealed, a simple water air-lock installer with the end of the pipe lower than the lid, but above the biofertilizer level. The air lock bottle is hung below the water level to avoid siphoning. Depending on ambient temperatures, the container will be left to ferment for 4-6 weeks, depending on air-lock temperatures, until the bubbling will have stopped. If, for whatever reason, you need to open the barrel, adding more molasses and yeast will expel the air. The 200L drum or container should maintain a perfect airlock for 1 month.
- Magnesium, Molybdenum, Magnesium Sulphate, Calcium, Zinc, Manganese, Potassium etc. can be added to adjust recipes to particular cropping needs.
- Mix 1L of biofertilizer with 10L of clean water. Spray early in the morning or late in the evening, when the plant stomata are open

Fish Hydrolysate

- Cut, Blend, Mince Whole Fish or Fish waste & discards. The finer the fish bits, the more effective the fermentation.
- Add sugars (Sugarcane Molasses) at a 3:1 Ratio. (750g Fish:250g Molasses)
- Add 3 parts non-chlorinated water (Chlorine kills microbes) to 1 part ferment material (1L Fish Mince:3L Water)
- Add Lacto-Bacili to blended fish mixture, approx. 2 tablespoons / L (Kimchi/Sauerkraut)
- Ferment the mixture into a container covered with cloth or mesh for 2-4 weeks.
- Once completed , there should be little more than a faint, sweet vinegar smell.
- It keeps indefinitely

APPLICATION:

- Mix ½ tablespoon / L
- Use primarily as a soil drench
- Inoculate compost to boost fungal population
- Use in compost teas to boost fungal growth & add nitrogen. Use at ¼ strength for this application.

Fish or discards from gutting table fish are chopped into smaller pieces to go through a mincer.

The fish is minced into a finer meal.

Mixed with molasses and water at the given ratios.

Lastly lactic acid culture, in this case from soured vegetables, is added to the mix.

CalPhos

- This preparation supports plants entering the flowering cycle. Phosphorus feeds the root system and allows the plant to access soil nutrients and water
- It supports flowering and strengthens the plant's stems and leaves in preparation for heavy fruit sets, prevents and treats blossom end rot in tomatoes. If fed to animals in heat and during pregnancy it helps breeding efficacy and litter success rates.

RECIPE:

- Washed eggshells, seashells, bones, limestone or lime
- Char (Fry) the eggshells. Some turn brown/black and the others turn white. Burnt shells are the calcium source and the white ones are a phosphorus source
- Grind the shells in a mortar & pestle or blender
- Transfer to a jar and add 5 parts of vinegar to 1 part of ground shells
- The acid in the vinegar starts a chemical reaction and bubbling begins to happen as the process converts the ingredients into liquid calcium phosphate
- Once the tiny bubbles disappear seal the jar and ferment for 20 days.
- Filter into another jar and store for years.

APPLICATION:

- 1 tablespoon to 4L clean water for use in the flowering phase of plants and when the fruits are mature

Scorching smashed egg shells over the fire to start the chemical reaction. Black shell is relatively high in Calcium: white in Phosphorus.

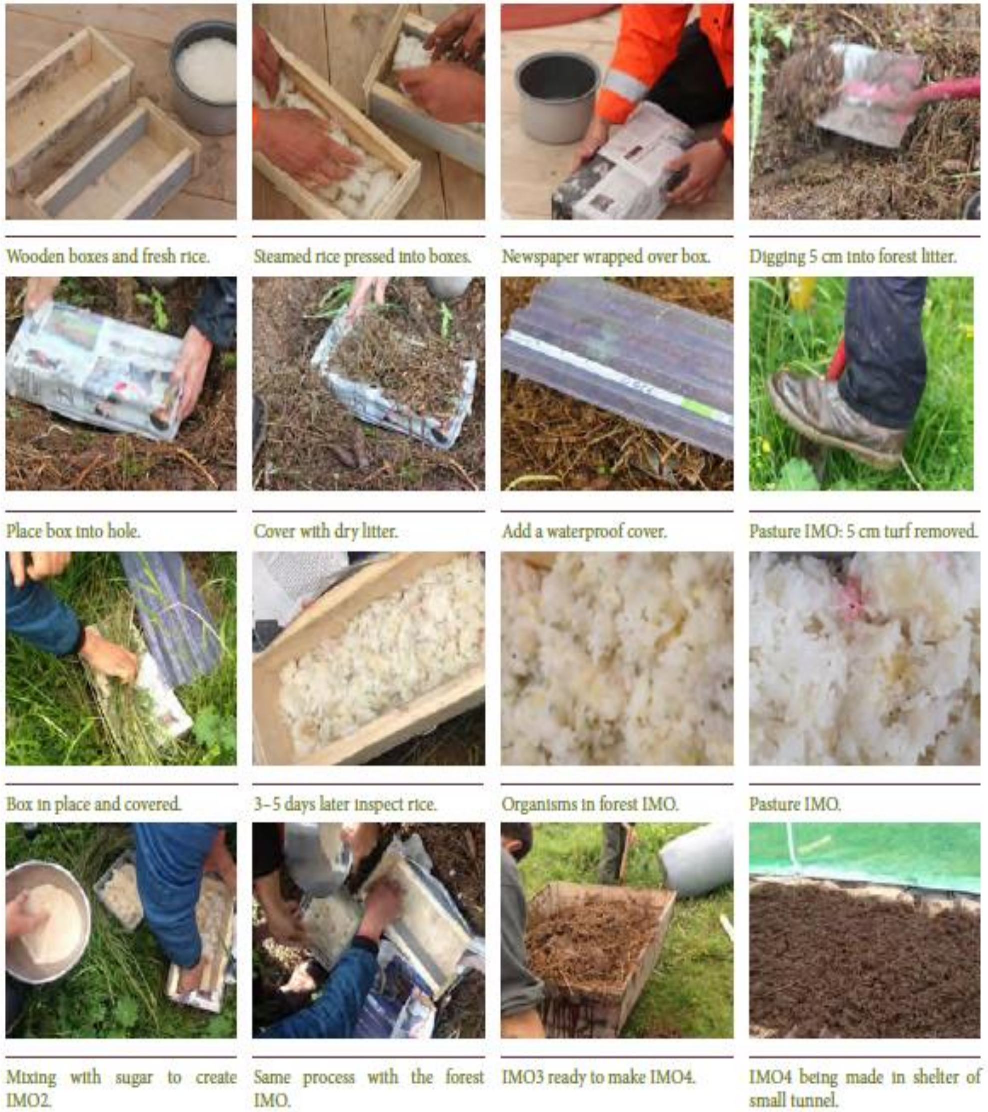
Adding spirit vinegar at a ratio of 5 parts vinegar to 1 part egg shell. The mixture immediately begins to bubble.

After 10 minutes or so everything has reacted. A strange odour and wall of foam now fill the container.

We cover with a compost sieving bag and leave to settle and ferment over the next 20 days. You can bottle and keep indefinitely after this.

Indigenous Microorganisms

- Indigenous Microorganisms (IMOs) form part of a recurring and holistic soil food web enhancing strategy for both annual & perennial crops.
- They can be collected and propagated using simple & accessible technology. They can accelerate the inoculation of beneficial MOs when implementing perennial fungal systems (tree crops) into a bacterial-dominated system (pasture)
- In order to be effective, IMOs should be used regularly, like Compost



Indigenous Microorganisms

- IMO 1
  - Fill a wooden box with steamed rice and place it in the habitat from which you will harvest the IMOs. Do not compact the rice in the box and leave enough airspace on top. Without air supply the anaerobic IMOs will take over.
  - Cover the top of the box with paper and secure it with a rubber band or tape.
  - The moisture content of the cooked, sterilized rice substrate will attract IMOs living in the soil.
  - Dig away 5cm of topsoil and place the box in this pit. For perennial crops collect in a woodland setting, while for pastures collect in an undisturbed grassland.
  - Cover the box with grasses or leaves and protect it from the rain with a loose lid.
  - In the summer 5 or 6 days are needed to collect and grow the microbes on the rice substrate.
  - The collected rice is called IMO 1.

Indigenous Microorganisms

- IMO 2
  - Mix unrefined sugar with the IMO in 1:1 ratio (1kg of sugar: 1kg of IMO)

- IMO 3
  - Dilute IMO 2 with water (1:1000) and mix with wheat bran or flour.
  - Bring to a moisture level of 65-70%. The consistency should help it lump up when pressed and loosen when shaken
  - After mixing, stack the bran mixture IMO 2 on a soil floor at a 30cm height.
  - Cover the heap with straw and ensure that the temperature does not rise over 50 degrees Celsius
  - It may need flipping over every 2 days, the cultivation speed depends highly on ambient temperatures
  - If the pile temperature is below 40 Degrees Celsius it must be in anaerobic conditions because of excessive moisture
  - If the pile temperature exceeds 70 Degrees Celsius proteins will be broken down by thermophilic microbes and lost through volatilisation
  - The pile may be turned over to control the temperature
  - In 5-7 days the temperature stabilizes and stops rising, the surface will be covered with whitish spores and lumbs of IMO colonies. At this point the pile is finished and the moisture levels will have dropped.
  - IMO 3 can be stored in breathable fabric (Hessian of Plastic Mesh vegetable sacks) in a barn or shady storeroom.
  - During storage, IMO 3 can become dry and reach 20-30% moisture. The organisms simply lie dormant.

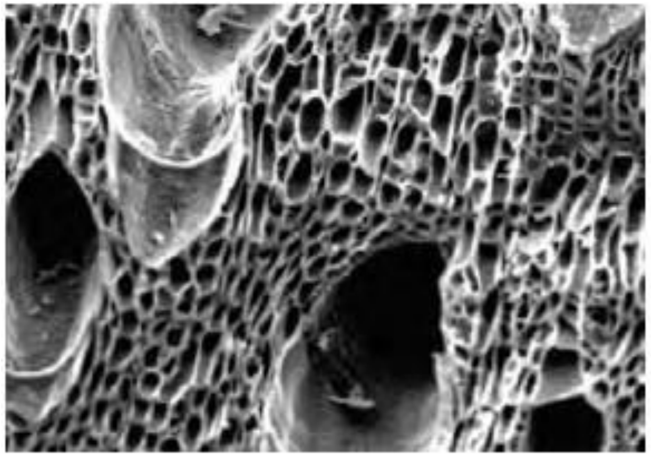
Indigenous Microorganisms

- IMO 4

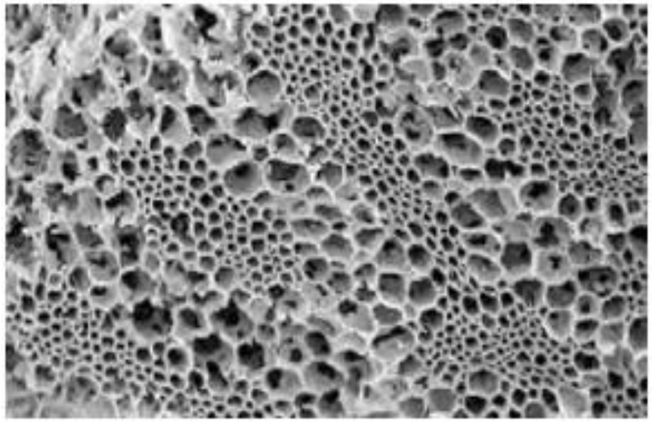
- Combine 1 part IMO 3 with 1 part soil.
- The Korean natural farming guides suggest mixing 50% of the soil in the mixture be from the field intended for the crops and the other half from undisturbed soil, so as to combine wild IMOs with those living in tilled / cropped soil.
- Mixing should be done on the soil floor in a 20 cm high pile, kept covered for 2 days.
- Can be used in potting mixes, as surface mulch or as an amendment when planting.
- IMOs support healthy & diverse soil fauna and should be collected and propagated annually for good results

BioChar

- The practice of transforming agricultural and domestic waste into fertilizer is thousands of years old. Char is naturally found in soils around the world as a result of vegetation fires and the discovery of Terra Preta in the Amazon has created a Mythos and elevated scientific interest around Biochar.
- Studies find that application of Biochar leads to increased crop yields, mitigation of fertiliser runoff and nutrient leaching, increasing soil moisture levels. It fosters the growth of soil microbes essential for nutrient absorption (particularly mycorrhizal fungi). The carbon in biochar can remain stable for millennia, providing a simple and sustainable means to sequester historic carbon emissions that is technologically feasible in all contexts.
- Biochar is a nutrient carrier and a vast habitat for microorganisms (it has a surface area of up to 300m2 / gram). It needs to be charged with microorganisms for it to become biologically effective. Due to its porosity it can incorporate up to 5 times its own weight in water & dissolved nutrients. This absorption capacity depends on the type of biomass used and the pyrolysis temperature.



Pores in the walls of the pores in the pores: a fractal pattern.



Different materials give different microscopic structure, but the surface area is always vast. Images courtesy of Albert Bates.

BioChar

- Biochar has a hush CEC (Cation Exchange Capacity), which helps leaching of mineral nutrients through the binding of molecules, hence it has huge potential for use in many areas of the farm and in bioremediation work. The high CEC and high absorption capacities make it a very powerful nutrient carrier.
- If Biochar is incorporated into the soil empty it will begin to lock up nutrients and water and this will result in the initial inhibition of plant growth. To prevent this and to use it optimally, it should first be charged with nutrients, water and microorganisms by placing it into compost
- When Biochar is created from biomass approximately 50% of the carbon that the plants absorbed as atmospheric CO2 is fixed in the charcoal. Biochar offers the opportunity to remove excess CO2 from the atmosphere and sequester it in a virtually permanent and environmentally beneficial way.
- The development of modernised and highly effective wood gasification power supply units opens up fantastic opportunities for farm application.

BioChar; The Cone Pit Method

- Dig a cone-shaped hole 90 cm deep and 1,2 m wide at the top in a safe location
- Biochar should be made with an efficient, smokeless burn
- Once the initial fire is established layers of dry wood are added. When ashes form on the edges of the wood it is time to add more
- The constant addition of wood covers the char and the cone pit does not allow oxygen at the bottom.
- When the pit is full add a thin layer of wood as a lid
- When the top layer is caught spray the pit with water. A pit this size will require several minutes of constant watering.
- Smash or grind the char and transfer it to a basin.
- Soak the pile for 2 weeks in water and urine for proper hydration and nitrogen inoculation
- To inoculate the hydrated char with microbiology mix it evenly through healthy aerobic compost by adding it continuously as the compost is turned
- Biochar cannot be used in the Berkeley Compost method as it will upset the C:N Balance.
- Biochar can also be charged with manure by adding 10-20% biochar to barn bedding to catch excess liquids and reduce ammonia emissions

The initial fuel fire is needed to light the subsequent layers of wood. Let this catch and get hot before starting to add layers.

The fire will smoke briefly as new wood is added, the quickly become smokeless. When ash begins to form on the logs add another layer.

The very last layer will not char completely, but can be reused in the next pit. Let it catch completely before extinguishing the pile.

It takes constant watering from the hose for 5–7 minutes to extinguish the pit completely. Make sure water has penetrated all the way down.

Urban Permaculture & Agriculture

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Urban Permaculture

Urban agriculture can be defined as the practice of agriculture in urban and peri-urban neighbourhoods, including transformation and distribution of commodities.

It involves growing edible, medicinal and functional crops on the surfaces available in the urban environment, from industrial wastelands and abandoned sites to urban gardens, public parks, balconies, rooftop and vertical farming. The term “urban agriculture”, by its implementation in the city, implies the interaction of thousands of human beings around the agricultural activity. Urban agriculture should not be considered solely as a food producing activity, but also as a full part of the social fabric of urban neighbourhoods.

Shortly, Urban Agriculture is any activity that falls within the lines of growing, processing and distributing food, crops and / or animal products within the confines of a densely populated area.

It can take a number of forms, such as: Community gardening, Roof gardening, controlled environment agriculture, vertical agriculture, ecologically intensive agriculture. Urban agriculture covers horticulture, livestock, fish farming, agroforestry and urban beekeeping. Staple crops and fodder crops are usually not included in urban agricultural projects, but can be used as measures to cover & rehabilitate damaged soils

Benefits of Urban Permaculture; Social

- Spaces allowing cultures and generations to meet
- Increased food safety
- Education to sustainable agriculture, training
- Reconnection to nature
- Access to healthy food
- Physical exercise
- Feeling of well-being and stimulation of creativity through greening
- Being more present and responsible in the local community
- Social and professional reinsertion

Benefits of Urban Permaculture; Ecological

- Awareness about sustainable agrifood systems
- Buffering of rain and storm water
- Water cycling, waste cycling
- Thermal insulation of buildings
- Temperature regulation
- Air cleansing
- Reduced CO_2 emissions through less transport and carbon capture
- Enhancement of biodiversity

Benefits of Urban Permaculture; Economic

- Stimulation of the local economy
- Growth of the job market
- Affordable food
- Territory and building differentiation (BREEAM, BATEX, …)
- Efficient land usage of “wasted” space
- Spreading of the agricultural production
- Lower employees turnover
- Lower production costs

Balcony Gardens

This is the smallest and most basic type of urban garden. It is the urban inhabitant's last stand and a natural refuge for those living in apartments. Be it an open or closed balcony, this growing environment presents certain challenges:

- Uncertain solar exposure (either full sun or barely enough at all), which can leave houseplants wanting or cause them to be scorched. Also, lateral sunlight, rather than vertical which is also filtered normal glass does not have the same quality as direct natural sunlight coming from the top, which can have a confusing effect on plant stage development.
- Ventilation issues: Plants need proper ventilation and air circulation (air drafts and currents) to ensure a healthy, disease-free environment for their development. It can prove difficult to properly air out an enclosed space without the use of fans. Conversely, an open balcony may be vulnerable to winds & rains and can sustain the brunt of adverse weather. The wind can damage and stress plants and contribute to water evaporation.
- Fertilization, aside from a very well-thoughtout nutrient production system (In-Door Vermicomposting), needs to come from the outside of the garden. Sourcing low-impact fertilizing inputs can prove to be a challenge.
- It can prove to be a logistics and clean-up challenge.
- Irrigation: Manual watering is very time-intensive and, more often than not, the amateur gardener might not ensure optimal irrigation. In-door automated irrigation systems require quite advanced plumbing skills. Soil can dry out because of reduced soil volume and direct heat can increase temperatures on planter walls which, in turn, hasten evaporation rates.

Until gardens on rooftops, building walls and in apartment complex courtyards will become mainstream, certain herbs, aromatic, medicinal and oxygen-producing plants can be grown in the in-door environment, providing a wide range of economic and health benefits.

Terrace & Office Gardens

The Terrace garden is situated on a surface with access to vertical sunlight. It offers growing conditions very similar to natural ones, except that the plants are grown in large containers.

In the future, implementation of such public amenities will cover the city-scape's rooftops with terrace gardens, with an immense potential to ensure the buildings' energy balance, partly mitigate climate change and produce food crops.

However, most old buildings were not designed with gardens in mind, so water and soil load considerations and calculations must be made by specialists so as to ensure the structural integrity of the buildings where such gardens are desired to be implemented. Presently, Construction Engineers are considering, learning and designing new solutions of integrating gardens into building infrastructures, so that they will benefit from integrated irrigation & drainage systems, structural elements for securing soil-holding planters, wind-breaks etc.

Terrace & Office Gardens

After overcoming structural (securing planters) and drainage (filtering the run-off water and directing it to the rooftop's drainage gutters) challenges the Terrace Garden can be safely implemented, with the only remaining impediments being irrigation, wind protection, general safety considerations for the gardeners, weather-proofing and the actual garden maintenance.

Implementation work is extensive and heavily material-dependent as soil has to be brought to the roof and well-insulated so as not to leach into and clog the building's water run-off systems. All of the structures need to be well-secured as not to pose a hazard, as well as given weather-proofing treatments.

Terrace & Office Gardens

Rooftops represent quite a unique microclimate: they are a light-reflecting thermal mass, in full sun, but also in full wind. The designer can choose to adapt to the environment or adapt the environment to create niches.

Large planters and planting spaces offer the advantage of enabling the growth of large perennial plants with large root systems.

Office gardens are a source of joy & health for those who work full-day shifts sitting down in office complexes. They have been proven to boost productivity & employee health.

School Gardens

- Nature is humankind’s first teacher. As such, every school, office or other public educational facility would greatly benefit from the presence and yields of a functional garden. It is the perfect setting for the outdoor classroom and is the ideal study aid for subjects like Biology, Chemistry, but also Mathematics, Physics, etc.
- Teachers can act as coordinators and share the garden, classrooms could have their own test plots, the food produced could easily be used for school lunches and it could also serve as a composting site for the resulting organic scraps.
- In fact, the possibilities are limitless, and the potential arises that schools could pioneer the prototyping of larger-scale organic waste composting systems, which, in their finite form, could travel back down the loop and serve as natural fertilizer for the garden.

School Gardens

- Natural learning environments offer students greater psychological well-being than the often-confining conventional schools, not to mention that the garden itself can prove to be a worthwhile energy sink for active children. Caring for a space together, sharing tools and working together teaches the young learners a set of invaluable soft skills necessary for effective collaboration.
- School gardens are a chance to educate a new generation of children with a climate-proactive mentality and to equip them with the practical and soft skills so relevant for them to be changemakers in a world challenged by the growing population and with so many systems which have invisible environmental costs.

Community Gardens

Urban Community Gardens bring the ability to re-green the urban environment into the hands of the citizens and are heavily reliant on a motivated and responsible local community. In fact, one of the hidden benefits of Urban Gardens is that they serve as a practical foundation for the local community to learn how to navigate the tensions of communal life and grow into a self-organized local action group with the potential to gain and develop an innovative local administrative capacity with the potential to alleviate the responsibility and workload of central administrative bodies.

Urban Community Gardens can prove to be viable models applicable in cities & neighbourhoods, especially now, as the global urban landscaping movement is challenged by the rising tensions of climate change, food security and population growth. The legal & administrative climate is following suit, becoming more and more supportive of such initiatives and there is an increasing number of opportunities for such gardens to receive public officials' support in their implementation, development and maintenance as a mainstream modality to streamline efficient Urban Development Strategies.

Setting up an Urban Community Garden depends, of course, of its context, scale and objectives. However, the set-up phase is just a spark that sets off an entire course of development and change at all levels for the benefit of all those involved.

Community Gardens

The City offers quite a unique microclimate for growing crops: Concrete & Light Reflecting surfaces tend to hold and diffuse heat, Water and Electricity are readily available, so are other services relevant to the running costs of a garden. Conversely, Air Pollution, Vandalism & Theft, Pests (Rats, Cockroaches) and wind-blown Litter are some of the Urban Garden's worst downfalls.

As Urban soil is, oftentimes, of very poor quality, the easiest way to ensure the productivity of the garden and to ensure a solid foundation for its unhindered development is to bring in soil from construction & composting sites and to set up planting areas in the forms of raised beds & bordered mounds. On-site Chopping, Mulching & Composting of the waste plant material and local residents' vegetable scraps will further serve to improve soil quality, its water-retention capacity, to create a habitat for myriads of microorganisms for it to serve as a solid foundation to re-build a functional & productive ecosystem.

The Urban Garden is the ideal site to develop a dense planting system, mixing annual vegetable cropping beds with perennial areas (Mixed Orchards, Medicinal & Aromatic plants, Vines, Strawberry Patches, Wildflower Patches) so as to ensure harvests for both the present moment and for the future.

Community Gardens

Just as with any other agricultural endeavour, Urban Gardens benefit from the implementation of an automatic irrigation system coupled with a rain sensor. Water can be reticulated through drip tape for the annual beds & protected spaces, and can be fed to sprinklers which will serve to keep the lawns healthy during the hot summer months. These can be supported by hand-watering, which can sometimes be a very relaxing pastime.

Ecological Niches (Rock Piles, Ponds, Shrubs etc.), Wildflower Patches and Perennial Aromatics will help to bring back a resilient and diverse ecosystem and pollinators which help maintain, grow and balance the ecological health of the System.

The Garden can also serve many other functions: community centre, event space, children's playground, educational site, composting centre, all of which add to the richness of the urban landscape and represent multi-faceted local solutions for global issues.

Furthermore, Fruit-Producing trees will provide food security and ecological benefits for years to come.

Urban Gardens can serve as a natural haven in the midst of the cityscape and, besides food production, they can provide a place where city's inhabitants can relax and socialize, celebrate, connect and care for their environment. As stated in the beginning, perhaps one of its greatest functions is to bring the local community together around a shared goal and to grow a trend of co-responsible and caring stewardship of the environment around us.

Allotment Gardens

- Permaculture can be specifically oriented towards allotments.
- This can often be rented from your local council.
- However do check on any existing restrictions in the tenancy agreement and design within such limits.
- Although such plots tend to be small, it is still possible to design clearly identifiable zones.
- Tap water is often available, however do consider appropriate water conservation techniques.

Urban Farming

Urban farms consist of intensive production spaces which aim to extract the most value out of the available space, aiming to maximize production per cultivated area through innovative, efficient & creative human-scale cropping systems & management strategies.

So far, most successful Urban Farms have arrived at a somewhat standardized set of growing techniques: biointensive market gardening in modular protected spaces (CaterPillar Tunnels), using other season-extending techniques and innovative, ergonomic and efficient tools, so as to ensure minimal labour and high productivity.

The majority of the income generated through this business model comes from annual, short-cycle niche crops, with a high degree of profitability (Lettuce, Salad Mix, Baby Greens, some aromatic plants), therefore making the enterprise very adaptable to the fast-changing trends of the buyers' markets (CSA, Farmers' Markets, Restaurants, Grocery Stores etc.)

(According to an economic projection of the Permaculture Research Institute of Romania, in 2019 a 1000sqm Urban Farm would generate an annual turnover of EUR 10,000 only from the sale of vegetables (Romanian Market Prices, Price Range between conventional & Certified Ecological)

Urban Farming

Direct incomes from vegetable or seedling production can be supplemented with passive incomes from other activities, such as community & educational workshops & events, sub-letting the space etc.

Another important aspect to increase the Urban Farm's profitability and resilience in time is to reduce distribution costs through a production & distribution model which includes the support of the local community (**C**ommunity-**S**upported **A**griculture - **CSA -** The consumers contribute to the farm by buying long-term subscriptions at the beginning of the season and participate voluntarily in the production).

If managed properly and with an efficient growing strategy, due to its small size, commercial Urban Farming enterprises can be operated by a single person in less than full-time, adding to the farmers' quality of life and adding to a diverse, fulfilling life. Most Urban Gardeners practice Market Gardening seasonally as a way to supplement their income and to create value to the environment and the community.

In order to keep up with the times, Urban Farm management must be holistic, agile, dynamic, adaptive and oriented towards the local community and market's needs and fluctuations.

Urban Farming

Regenerative Potential & Capacity

Urban Farm cropping systems have immense regenerative potential through the integration of techniques such as Perennial Hedgerows, Perennial Plant Cropping Systems (Strawberry, Asparagus, Rhubarb, Berries), Wildflower Meadows and Mixed & Intercropped Food Forests Orchards.

These mixed ecosystems provide diverse & resilient perennial crop yields along with annual crops, benefitting the ecosystem through the creation of a balanced trophic system with a large diversity of flora which attracts pollinators, creates biomass, improves water retention and minimizes soil run-off & erosion.

Mixed cropping systems also offer a higher degree of resilience than monocultures. Nowadays, unpredictable weather events, pest waves and drought are among the main reasons for crop loss. Planting more diverse crops guarantees that a large part of them will succeed and the harvest will be staggered throughout the season, reducing the risk of the farms' failure.

Urban Farming

Case Study: SPIN Farming (Small Plot Intensive Farming)

Access to land is one of the greatest barriers preventing new farmers entry into the agricultural sector. Also, Urban Real-Estate comes at a premium price due to rising industrialization in urban expansion into the peripheries. Cities have plenty of underutilized or “frozen” spaces suitable and available for short-term intensive annual crop farming, such as for sale plots, backyards, industrial areas etc.

SPIN Farming is, simply put, using an abandoned or unused piece of land in the city or the countryside for setting up a vegetable production plot which is rented or leased to the mutual benefit of the owners and the farmer.

While small in scale, it has the capacity to alleviate the systemic barrier of access to land and to produce nutritious food for the local community in the global context in which urban settlements are being transformed, little by little, into food deserts, which means that the sites for actual food production are very distanced from the end consumers, making them dependent on fragile and damaging distribution and resale mechanisms.

SPIN Farming production is intensive, modular and relies on portable infrastructure and tools. In the eventuality that the land receives a different use, the infrastructure can be relocated in as little as a few weeks, if the need arises to vacate the land.

Preparing a SPIN cropping plan accounts for a succession of several crops during the growing season. It has to be implemented in a way that you do not put twice the same family of vegetables during the rotation, in order to avoid spread of diseases and to ensure different complementary nutritional needs of the crops.

Vertical Farming

Very rapid climate change will also pose problems for the way agriculture is done at the moment. It is precisely because of these future problems that scientists concerned with environmental issues predict that if the classical agricultural system does not change, soils will be in great danger of degradation, and large areas for agriculture will become unusable. This will actually mean a loss of productivity especially since by 2050 statistics show an increase in the world's population to 9.8 billion inhabitants (UN, 2017), and the vast majority will live in urban areas.

We need radical changes (Despommier, 2009) in the way we produce our food, to recognize that food production can move to the urban environment, often very close to urban centres (Despommier, 2011a). We can greatly reduce the intensive way of farming, and the concept of vertical farming can be applied to every urban centre, regardless of the geographical area in which it is located (Despommier, 2011a).

Vertical Farming

Food production in vertical farms can revolutionize the way the planet's population produces food (Despommier, 2009), becoming more aware of the accessibility of production, the quality of products and the use of production in a sustainable way. But the production costs, the financial benefits and the environmental impact of intensive production of vertical farms are not certainly established (Butturini, Marcelis, 2020)

There are more and more advantages of widespread application of vertical farming (Despommier, 2011b) in urban areas:

- All year round production
- Production is not influenced by weather
- Increased food production; no loss
- Tolerance to ecosystem restoration
- A system that uses little water
- The distance of food production is considerably reduced
- Greater control over products
- Quality products
- Jobs
- Transforming grey water into drinking water

Peri-Urban Agriculture

- Peri-urban agriculture includes cropping activities on large farmland on the outskirts of cities, such as staple crops, forage crops and livestock production, but can also involve social and recreational farming activities.
- Peri-urban agriculture, while less of a cluster being part of the city itself, is rather an agricultural boundary of the city. It stands as a bridge between the city and the countryside (Piorr et al. 2018), and impacts greatly the landscape of the suburban neighbourhood.
- Peri-urban agriculture contributes greatly to the food security of cities (Opitz, 2016). Opitz argues that the agri-food system around cities could follow the following scheme: urban agriculture included in cities, urban and peri-urban agriculture mingled together in the suburbs, peri-urban agriculture around the borders of the city and rural agriculture in remote regions.
- According to Opitz (2016), urban and peri-urban agriculture differ in most of their characteristics. Their difference in scale makes the products, commercialization paths and the bulk sizes very different while remaining complementary for the food security. However, while peri-urban and urban agriculture respond to different food needs of the population, both can do better in terms of transformation pathways. Urban and peri-urban agriculture tend to provide fresh produce but could improve further food security of cities if they provided conservation products as well, reducing losses and broadening offers. Therefore, urban and peri-urban agriculture need to be paired with transformation industries.

Peri-Urban Agriculture

- As reported by Piorr et al. (2018) and according to ADEME (2017), the peri-urban farmland is being pressured by development of the city through the growth of housing, commercial and industrial areas as well as by the developing transport infrastructures. The peri-urban farming lots are being steadily converted into building plots.
- Zasada (2011) explains the potential of urban farming for agro-environmental schemes. Due to the higher land availability in the peri-urban areas, farmers are more likely to implement measures increasing biodiversity, such as hedgerows and flower strips. The lack of space in the center of cities and the little size of plot space, as well as the lack of land-safety in urbanized areas (short term farm leases) impede the investment in perennial biodiversity-enhancing zones.
- However, peri-urban agriculture lies under the pressure of the continuous expansion of cities. Economical matters are hereby significant: the price of farmland surrounding the cities is rising due to on one side the increasing urbanisation, also with the goal of reducing traffic in the city, and on the other side due to the proximity with the city (higher value crops). These factors tend to foster speculation on peri-urban farmland prices (Livanis et al. 2006).

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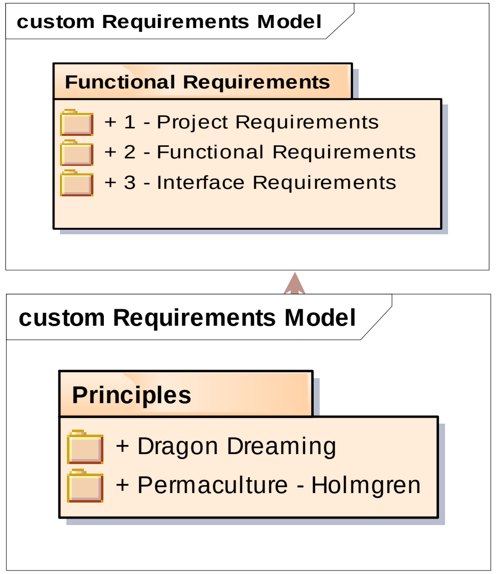
Principles and Requirements

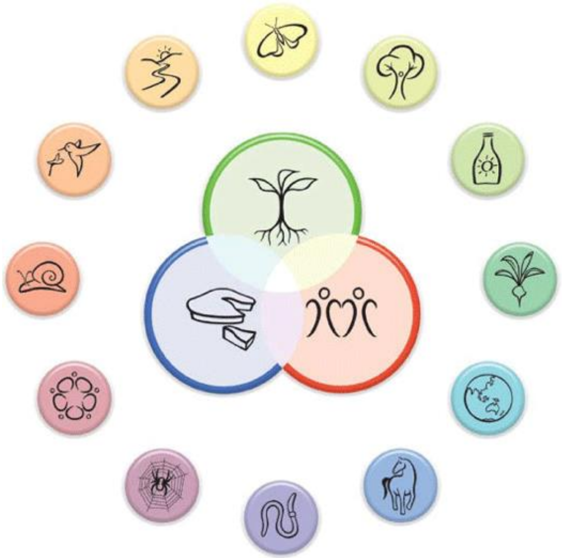
System Specification

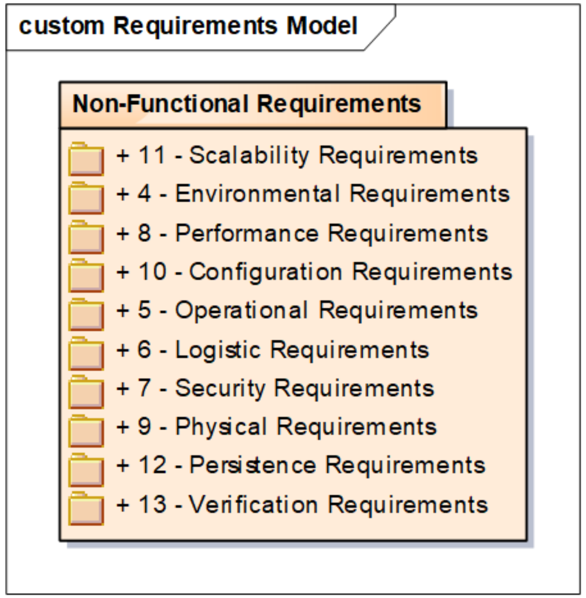
Systems science provides a means of understanding complex processes based on principles.
The system is specified in Architecture, Schema and process.
The Architecture details the functions and relation between the component of the system.

Permaculture principles are requirements for systems of systems' design

The Requirements are divided into two sub-catalogues:
1. The Functional requirements
2. The Non-functional requirements



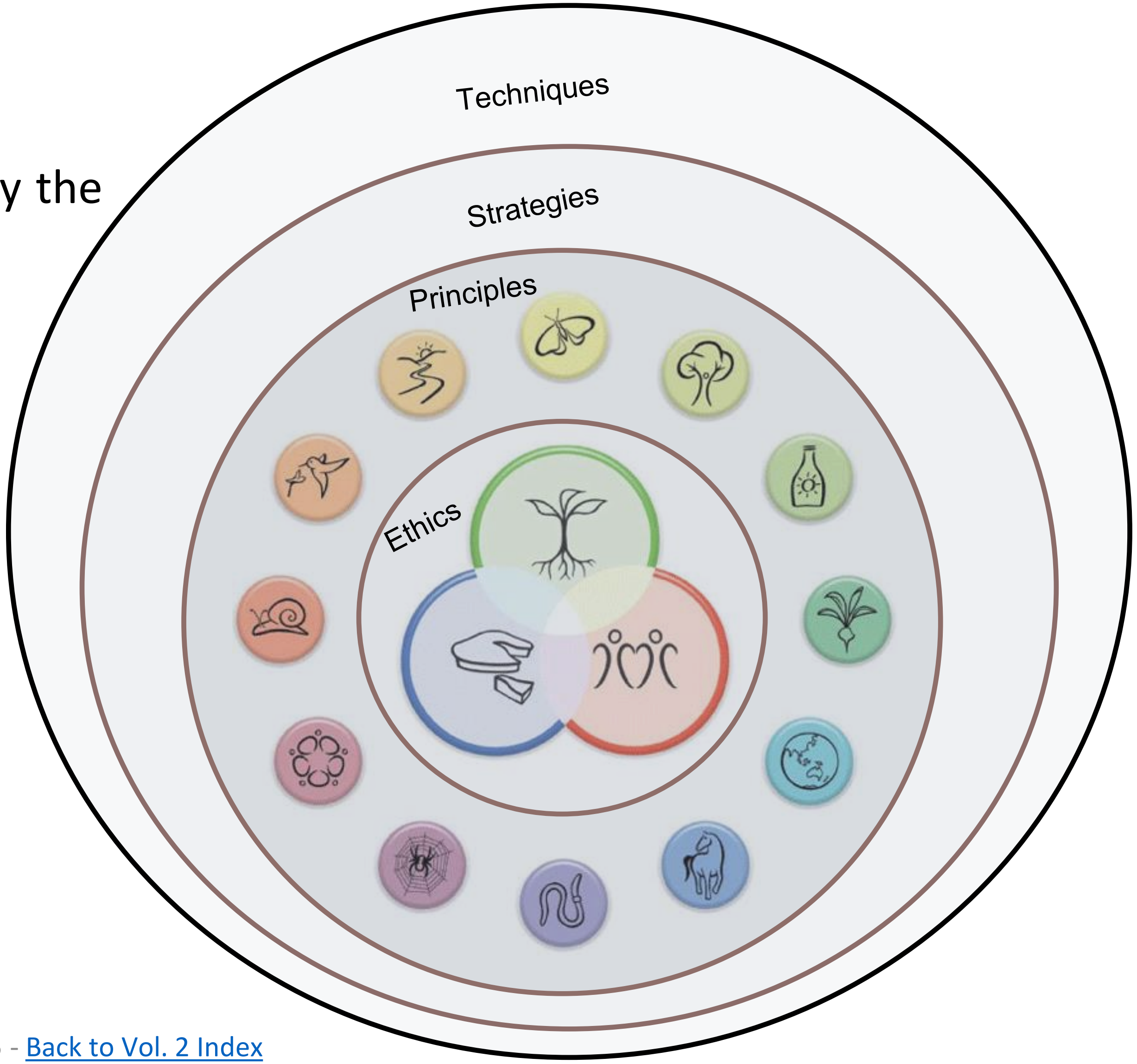




Permaculture Methodology

A Permaculture design Methodology is defined by the following elements:

1. Its Ethics and Principles
2. Its Design Process
3. Its Design Tools
4. Its Deliverables/Outputs

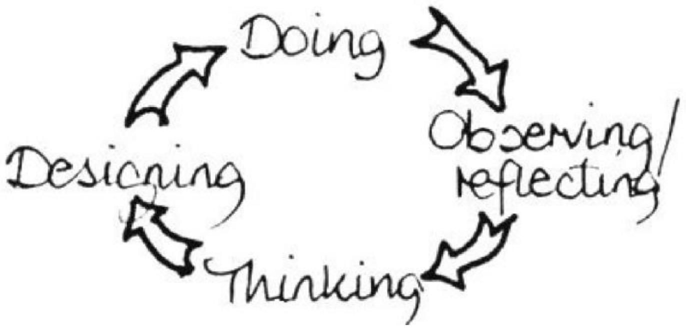


Design Process – Permaculture

This chapter shows the process used to design. The process is supported by a structure / framework / methodology. This structure is the design process. A working methodology is a way forward, which allows you to avoid omissions.

One thing to remember is that there is no single working method. Whatever the working method used, the **Action Learning cycle** which represents the natural method of human learning must be taken into consideration.

This very same concept is described and used in different traditions, such as the aboriginal one reflected in **dragon dreaming**, in the **Indian** one found in the medicine wheel or in **the tarot**.



Magic tool	Action	Dragon Dreaming	Element	Tetra grammaton	Tree of Life Plane
Wand	The idea being ignited	Idea	Fire	Yod	Molecular
Cup	unrestricted emotionally oriented imagining	Dream	Air	Heh	Gaseous
Sword	discernment and of putting limits	Planning	Water	Vav	Liquid
Pentacles	physical work and resulting products	doing e celebrate	Earth	Heh	Solid

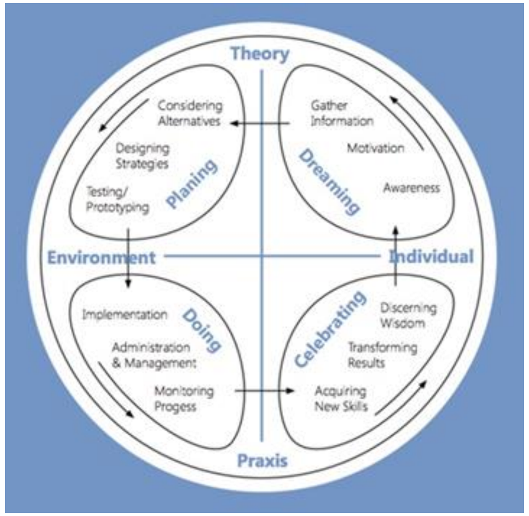
"The four implements or mental tools on the Magician's table are Wand, Cup, Sword and Pentacle."

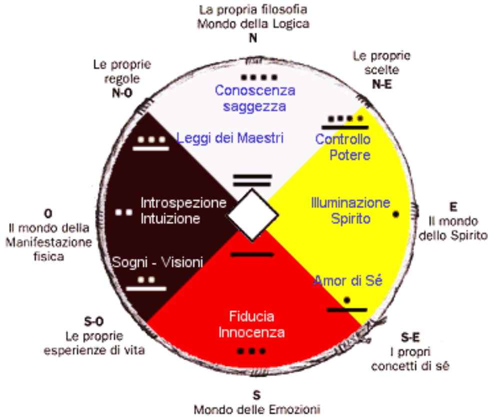
The basic tools of Ritual Magic are associated with both the letters of *Tetragramaton* (Yod, Heh, Vav, Heh) and the four elements (Fire, Water, Air and Earth) respectively. These tools become instruments for the working of Practical Magic, the magic of leading fully functional and fulfilling lives. These are the esoteric tools at work in the world.

1. I have an idea. The idea being ignited is the **wand**. It is also the first plane on the Qabalistic Tree of Life, the Archetypal World of *Atziluth*, known to scientist as the molecular state.
2. Then I fantasize, I create. This unrestricted emotionally oriented imagining is the **Cup**. On the Tree of Life, it is the second plan, the creative World of *Briah*, the gaseous state.
3. Next is the act of mental discernment and of putting limits on my ideas and imagining order to actually manifest the project is the **Sword**. This is the third Qabalistic plane, known as the Formative World of *Yetzirath*. In scientific terms Yetzirath is associated with the liquid state.
4. Finally, I finish the physical work and resulting products are the **Pentacle**. The Fourth and final phase on the Tree of Life is called *Assiah*, and in the Manifest World it is the solid state.

Design frameworks and process

The same natural sequence is used as guidelines in several design frameworks and process.
Mother Nature, as a reference designer to take in account, has already performed thousands of heuristic cycles where solutions and adaptation have been tested and results have driven evolution toward our reality.
It is thus natural to see how different past societies have developed traditional process approaches with specific connections with their own traditions. The Aboriginal culture in Australia, which really contributed to the definition of permaculture (*see Introduction in this regard*), was used to believe in longlines sprouting from the universe into the horizon and to allow the creation of reality in dreams.
A schematic pattern of the '*Dragon Dreaming process*' is provided below:





Patterns similar to the Dragon Dreaming Wheel are also found in ecological systems, in the formation of weather, in the Native American Medicine Wheel and even within our bodies; it is the structure which we carry in our brain.

One symbolic aspect amongst many is the analogy to the four seasons (winter, spring, summer, autumn), as well as the four phases in the life of a human being (childhood, youth, middle age, old age).
A day can also can be depicted by this wheel: it begins with the 'dreaming' in the night, the early morning 'planning', the 'doing' in the afternoon and – if a person is wise – a celebration in the evening.
The process leading to the definition of the different elements is presented as a sequence and information flow.
The following chapters will detail each step of this process in further details.

Project Approach Models

A project is a series of activities aimed at bringing about clearly specified objectives within a defined timeframe and with a specific budget.

Every discipline such as industry, agriculture, Software industry and permaculture too, developed a guideline to support the designer to follow a process to go from the preliminary steps to the completion of the proposed objectives.

A project includes:

- Clearly identified partners and involved actors, including the **primary target group** and the **final beneficiaries**.
- Clearly defined **coordination**, **management** and **financing arrangements**.
- A **monitoring system** to oversee and follow implementation and to support project management.

Projects differ in size, scope cost and time, but all have the following characteristics:

- A ‘start’ and a ‘finish’, in other words a starting date and an end;
- A life cycle involving a series of phases in between the beginning and end;
- A budget;
- A set of activities which are sequential, unique and non-repetitive;
- Use of resources which may require coordinating;
- Centralised responsibilities for management and implementation;
- Defined roles and relationships for participants in the project.

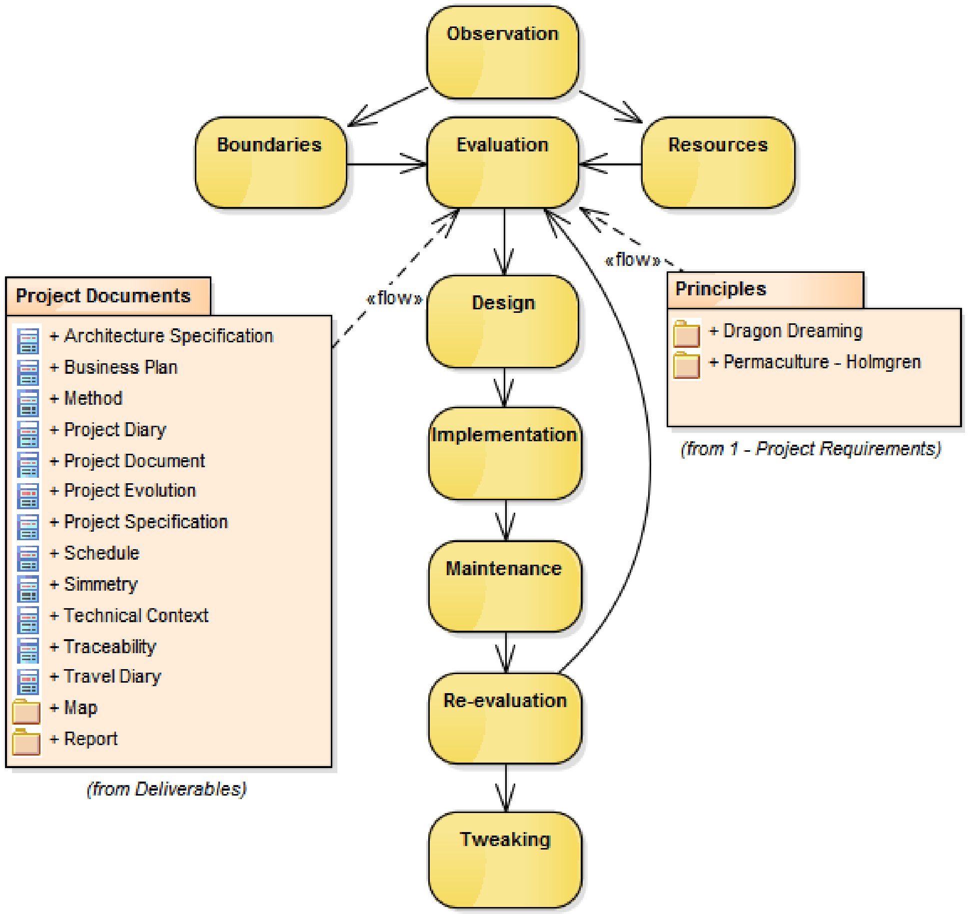
The term “project” could therefore be taken to mean a group of activities undertaken to produce a Project Purpose in a fixed time frame.

Several project approaches and framework are available Some are the following:

- Dragon dreaming
- Design Web
- V-Model
- Agile
- OBREDIMET
- Project Cycle Management (PCM)
- Permaculture Design Process aligned with a Project Management Process

Process - O'BREDIMET

OBREDIM(ET) stands for **Observe; Boundaries; Resources; Evaluate; Design; Implement; Maintain; Evaluate; Tweak**



The Evaluation merges the dream to…..

- Scope
- Objectives
- Actions
- Elements

Process - O'BREDIMET

Observation – The first Holmgren principles and basically the founding step of each Permaculture project.

Observe, without judgement and feel any possible trigger that can be gathered to your attention! Take the time, four seasons or more if possible, to understand an existing site or project context. Use all senses and record the physical features of the site and the environmental features affecting the site, or corresponding conceptual features in the case of non-land-based projects. Employ sector analysis where applicable, noting patterns and flows. Note the relationships of the observed elements and how they all function on their own over the course of time.

Being present in the moment and becoming aware of what emerges. Begin to notice the patterns that arise and how they make you feel. Something will trigger your attention. By identifying the trigger, these raw observations expand into more refined holistic goal statements.

Boundaries & Resources: Record physical boundaries and also define the conceptual boundaries of the project's scope. Those concepts are two side of the same coin. Every boundary can be a trigger toward a resource, as well a possible lack with a different perspective can became an infinite abundance.

Resources – Note the people, plants, animals and structures involved in the project and their potential skills or contributions, look or edges, transitions, energy flows, and sectors of elements interacting with the system as well as the current and possible future productivity of the physical site or project context. Check the availability of other resources, including financial and temporal. Use a client interview checklist if applicable and note needs and wants. What resources are available and where are the gaps? Keep the resource list expansive, meaning that you are gathering ideas rather than comparing or making decisions

Boundaries — start surveying, locating and establishing boundaries. Look for edges, transitions, energy flows, and sectors of elements interacting with the system. What are the limitations and edges around energy, including personal limits of the designer or design clients? Consider limiting factors – physical, cultural and other.

Do not attach to your interpretations. Note any information as data points.

Process - O'BREDIMET

Evaluation – Collate and analyse the information gathered in the first three phases of the design process in preparation for the remaining phases.

Note multi-functional elements and essential functions requiring multi-element support. Understand what is available to work with and consider whether the project will be feasible within the current parameters without further inputs or removal of limiting factors. Consider the evaluated information with respect to the permaculture ethics.Begin contracting the data you collected during your survey phase by sifting it through various analysis tools like SWOC (strengths, weaknesses, opportunities, constraints), zone/sector analysis, back-casting, scenario planning, input/output analysis, and cost/benefit analysis. Be sure to include an assessment of your motivations and perceptions before proceeding to the design step. Don't be self-limiting. This thinking process consists of an appraisal of comparing and contrasting data which leads to a synthesis of thought and a prioritization of next steps. You'll want to refine the goal statements.

Design – Place the elements on a site plan if applicable and in the light of evaluated information, with consideration of future inter-relationships and consequent outputs, to develop an integrated productive eco-system or equivalent. Refer to and apply each of the permaculture principles.

Design to reduce limiting factors. Employ tools such as zone and sector analysis, carthography, trade off between different options, functional analysis, Task Planning and financial analyis. Decide upon and plan the timing or phasing of the project's implementation.

During the Detailed Design the following activities are covered:

o Definition of system requirements (functional and principles)

o Definition of use cases

o Definition of the Element

o Functional analysis

o Processing of functional blocks and definition of physical blocks

o o Definition of architecture

o Choose a scenario and create a project specification. Include who will be doing what, where, when and how. Identify the scope of the project, timelines, budgets, action steps, accountabilities, decision making, tracking and evaluation processes. It's best to keep the initial design lean and straightforward rather than complex. Avoid trying to predict and control outcomes by providing excessive details (analysis paralysis).

Through the process of ideation and prototyping scenarios, you'll decide how to intervene in the system, thus generating the design proposal. From here on out you will begin doing/taking action through short iterations and rapid prototypes.

Process - O'BREDIMET

Implementation – Put the design and plan into action by commencing and carrying out physical work or other form of application.

Doing becomes the focus at this stage. You will likely go through multiple iterations of implementation as you prototype the design and continue to tweak the process based on the feedback loops and ongoing interactions/reflections.

Maintenance – Make small planned inputs to keep the system functioning at a healthy and productive level.

Here's where you go back to observation mode and the survey processes to gather once again an awareness of what's happening during each iteration. Through this process, you'll get a sense of what needs managing, maintained, further monitored or documented.

After multiple iterations or implementation/management finally, a solution will arise that meets the design challenge, however, note that the problem may have evolved by this point. Once a solution is identified, then a more robust implementation of the project might be performed.

Fail-soft
Fail-Slow
Fail-Safe
Fail-over
Fail-Back
Fail-Forward
Fail-Fast
Fail-stop

Design Principles

- **Each element performs many functions**
- **Each important function is supported by many elements**

You don't inspire others by being perfect.
You inspire them by how you deal with your imperfections.

Process - O’BREDIMET

Evaluation – Assess how well the system has performed, considering what has and hasn’t worked, and accept feedback. Creatively respond to contextual changes including issues of succession.

Hopefully you already designed in feedback loops. Gather the data you’ve been collecting on your reflections, design process and the project itself. Track and account for any renegotiations. Remember that multiple sectors and goals began in phase one. It’s time to integrate and weave together a story and celebrate our successes and learnings.

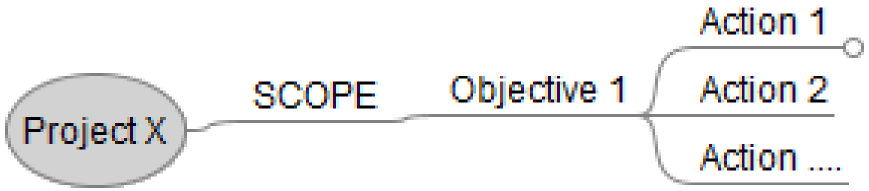
Now at this transition moment, or possibly the end of your engagement with the project, it’s time to do a more thorough reflection on the process, outcomes, goals assessment, and identify the impact(s) the intervention had on the system. It’s important to anchor back into the mind of the conscious observer so once again you can harness what emerges. You will likely have noticed that many new design triggers arouse along this journey. Each step was a design process woven into the more extensive design web that serves as the fabric of life and compels us towards becoming an integral coevolutionary change agent. Also, enjoy. Don’t forget to relax and enjoy what you’ve created! Hard work is important, but so is relaxation, down-time, self-care, and obtaining a yield.

Tweaking – Make minor adjustments as necessary to improve and optimise ongoing performance. Cycle around the previous two phases again, or the whole design process if required.

Tracking is a reminder to document! Be sure to use both qualitative and quantitative tracking tools. Track and account for any renegotiations. This final step often includes presentation, reports or documentation measures for clients, or in considering future phases of a project. Similar to management, we may want to make final tweaks to the new system established to refine its effectivity. Tweaking also allows for further design inspirations and challenges to emerge because we are observing and interacting while being aware of what arises within us and within the system. In essence, this indicates that the design cycle process is ongoing.

Design Process

Scope Objectives Actions



Definition of purpose, objective and actions is one of the key elements of the design. The project vision is deliberately projected from 1 to many.The design and implementation of the project no matter the size, implies a certain complexity. The great complexity but also the strength and justification of the design rely in the consistency between the aim and planned actions.

Since the connection matrix is complex, it is suggested to delimit the proliferation of purpose to one. The purpose constitutes the guideline, or the direction towards which the actions must aim.The determination of the scope and objective is not linear, and often there is confusion between desires, intents and personal goals respect to the community and long-term vision.

The scope can be achieved through projects with a specific objective realized through the accomplishment of different actions. The actions include elements that interact with each other.

Elements could have one or more of the following relationships or interconnections:

1. Functional
2. Exchange of information
3. Passage of material
4. Connection of flows

Design Process

Scope Objectives Actions

- The identification of the project and the concept idea is perhaps the most creative and visionary part of the design process where possible solutions to the proposed problems rise in the dreams and a coherent architecture and activity plan is proposed.The project can be analysed with a top down direction or the bottom up inverse direction.
- The purpose of the requirements definition is to provide the information and rules which include functional, structural, and behavioural models, and to support activities in the design phase.

In permaculture there are fundamental rules that are applied to the system of systems defined as principles that are nothing more than project requirements.

The model is divided into two sub-catalogues:

- 1. The Functional requirements specify how a proposed system will work and contains requirements and features that represent functional behaviour, features and rules that the system under design must present to fully implement the functionality desired.
- 2. The Non-functional requirements contain constraints and performance levels, the various operational parameters that define the environment in which the system will exist. For example, response times, security, strength, sustainability, redundancy.

System Requirement Specification

Permaculture principles are requirements to design systems. The purpose of the definition of requirements is to provide information about the rules which include functional, structural, and behavioural models, and to support activities in the design phase.

Functional analysis is a fundamental tool of systems design that allow the actual mapping of physical components. The phrasal specification of functions is the system's functional requirements. A functional requirement defines a function of a system or its component.

The Requirements are divided into two sub-catalogues:

1. The Functional requirements;

2. The Non-functional requirements

The definition of a system derives from the respect of certain rules which in modelling systems are called **requirements**. The requirements as a whole constitute the technical specification of a system.

In permaculture there are fundamental rules that are applied to the system of systems. Those are defined as principles that are nothing more than project requirements.

The Requirements model is a structured catalogue of end-user requirements. These are represented as either Requirement or Feature elements.

The model is divided into two sub-catalogues:

1. The ***Functional requirements*** specify how a proposed system will work and contains requirements and features that represent functional behaviour, features and rules that the system under development must present to fully implement the desired functionality.

2. The ***Non-functional requirements*** contain constraints and performance levels, the various operational parameters that define the environment in which the system will exist. For example, response times, security, strength, sustainability, redundancy.

The differing types of technical requirements are as follows (with examples):

The requirements are clear and unambiguous statement that describe a system in order to allow the design and development.

The first step of the design Process is to **analyse the inputs**. Requirements analysis is used to develop functional and performance requirements; that is to say that customer requirements are translated into a set of requirements that define what the system must do and how well it must perform.

The designer must ensure that the requirements are <u>understandable</u>, <u>unambiguous</u>, <u>comprehensive</u>, <u>complete</u>, and <u>concise</u>.

Requirements analysis must clarify and define functional requirements and design constraints. Functional requirements define quantity (how many), quality (how good), coverage (how far), timelines (when and how long), and availability (how often).

Design constraints define those factors that limit design flexibility, such as: environmental conditions or limits; defines against internal or external threats; and contract, customer or regulatory standards.

The project specification is not properly a design tool, as it actually is the backbone of the design, the place where the '*WHAT to do?*' is defined. It is a crucial step in the design process because it produces the foundation and pillars of the project proposal as well as its outcome.

Design Process

The differing types of technical requirements are as follows with related examples

Project Requirements (Principles)	The project shall use renewable energies to cover the 80% of energy consumption
Functional Requirements,	The chicken house shall provide thermal insulation
Interface Requirements,	The house shall have no direct interface with the pond
Environmental Requirements,	The project shall consider a maximum number of tons of CO_2 per year.
Operational Requirements,	The chicken house shall have a daily maintenance
Logistics Requirements,	The outcome of the production shall be transported to the distribution every day
Security Requirements	The farm shall protect the animal from wild hunters
Performance Requirements,	The farm shall produce an income of 500kEuro per Year.
Scalability Requirements,	The project shall be documented in order to allow a scale up
Persistence Requirements	The project shall be able to be self-sustainable in 10 years from the start of the activities
Verification Requirements	The electrical system shall be available to verification and inspection.

• Design Tools – Using the right tools for a project

The following sections describe tools and activities that a Permaculture Designer could take into account to create project proposals from a specified context, to solve the requested challenges:

- Mind Map
- Scale of Permanence
- Context Analysis
  - Observations
  - Element List
  - Cartography
  - Zone and sector analysis
  - Data Overlay
- Functional Analysis
- Schedule
- Budget
- Random Assembly
- Options and decisions

Each tool contributes to the outcome listed in the table below:

Tools	Outcome
Mind Map	Mind Map
Project Concept	Project specification
Observation	Diary
Element List	List
Functional Analysis	Diagrams
Cartography	Maps
Zone and sectors	Maps
Data Overlay	Maps
Functional Analysis	Architecture
TimeLine Analysis	Schedule
Business Plan	Budget
Random Assembly	Design Options
Options and Decisions	Trade Off

Design Tools – Using the right tools for a project

Tools and activities that a Permaculture Designer could take into account to design are listed below: project proposals from a specified context, to solve the requested challenges. Each tool produces a tangible design product.

Mind Map	Element List	Functional Analysis
Scale of Permanence	Cartography	Schedule and Budget
Context Analysis	Zone and sector analysis	Random Assembly
Observations	Data Overlay	Options and decisions

1

Each tool contributes to the outcome listed in the table below

.Design Process

Design Tools

Back to Design Tools

Tools	Outcome
Mind Map	Mind Map
Project Concept	Project specification
Observation	Diary
Element List	List
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Cartography	Maps
Zone and sectors	Maps
Data Overlay	Maps
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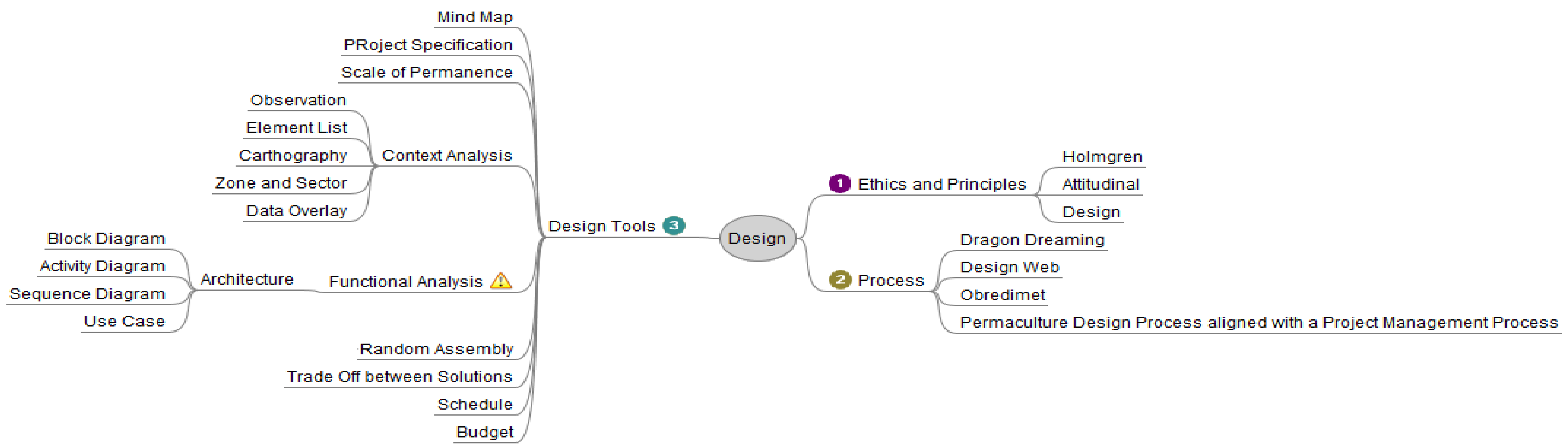
TimeLine Analysis	Schedule
Business Plan	Budget
Random Assembly	Design Options
Options and Decisions	Trade Off

Design Tools – Mind Map

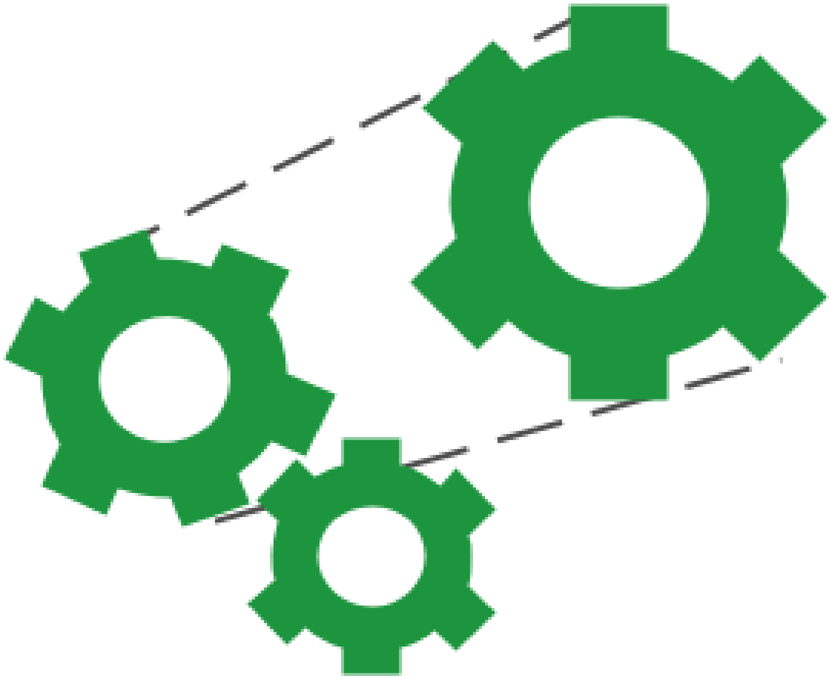


Mind mapping is a method for storing, organizing, learning, reviewing and memorizing information. It presents an overview and summary of a body of knowledge that fuses words and pictures together. Mind mapping seamlessly blends logic and creative thought to help us think more proficiently and effectively about the subject we are learning.

Mind Map

Several benefits of using mind maps:

- Helps you grasp a picture overview of the subject under study.
- Improves your capacity to explore detailed snippets of information.
- Helps improve your memory, retention, and comprehension of information.
- Helps you organize information into easy to remember chunks.
- Helps reduce mental clutter, cope with information overload, and overwhelm.
- Improved your capacity to manage your academic workload.



What Can Mind Maps be used for?

Since the dawn of the Internet Age, mind mapping has been growing steadily as a traditional method for collating, organizing, and expanding upon existing knowledge and information. Over this period, many people have shared extraordinary insights about how they have used mind maps to help them organize, manage and improve their lives.

Design Tools – Mind Map

Here are examples of ways professionals use mind mapping at work:

- Planning sales strategy
- Planning marketing strategy
- Organizing and managing projects
- Business planning
- Research and development
- Mind Mapping for Academic Success
- Learning
- Preparing presentations
- Brainstorming ideas
- Solving problems
- Thinking creatively and critically about topics
- Memorizing subject notes, books, and materials
- For general study and revision of information

Mind Mapping for Life Management

Here are examples of ways people use mind mapping to manage their life:

- Managing time
- Managing events
- Goal setting
- Keeping a diary
- Holiday planning
- Financial planning

The things that can be achieved and the amount of information we can manage at one time using mind maps is absolutely extraordinary.

·Design Tools – Mind Map - HOW?

Drawing a mind map involves a rather simple process. All that is required is an understanding of its underlying structure. Mind mapping is, in fact, a process that requires very little step-by-step explanation. For that reason, we will break it down for you here in only a few brief steps.

Here are several quick guidelines to help you get started drawing your very first mind map:

1. Take out a large sheet of paper and place it horizontally in front of you.
2. Draw a (coloured) central image or a circle that represents the topic you are going to be mapping.
3. Draw at least four thick organic looking branches radiating outwards from the central image.
4. Write key-words (headings) along these branches that represent the central image and the topic you are mapping.
5. Draw additional branches that extend from your main branches. The words on these branches are sub-topics of the words you wrote on your main branches.
6. Keep expanding the mind map outwards with additional sub sub-topics/keywords and branches.

Here are several mind mappings rules you should keep in mind when creating your mind maps.

- Use symbols to classify different types of thoughts and ideas.
- Use keywords on lines. Short phrases can also work well.
- Use multi-headed arrows of varying colour, size, style and dimensions.
- Create boundaries and borders to draw attention to specific branches.
- Create linear hierarchies of ordered numbers, lists and letters.
- Create a hierarchy of lines where they start off think then thin out as they expand outward.
- Draw thick branches that radiate outwards away from the central image.
- Create word-hierarchies by varying word sizes to emphasize their level of importance.
- Create a memorable central image and complementary visuals that come off the main branches.
- Draw different shapes to represent ideas and segments of the map.
- Vary branch colours, endings, thickness to distinguish different topics.
- Vary image colours, emphasis, and size to improve memory and recall.

Scale Of Permanence

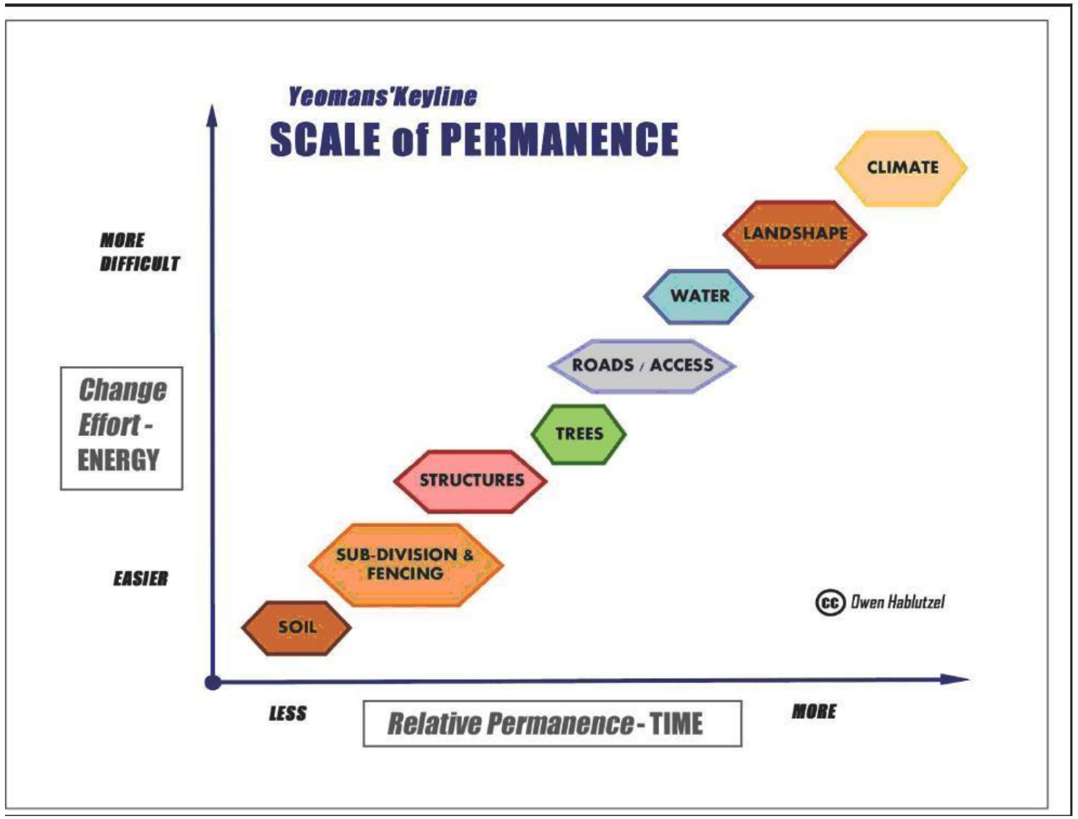
The permanence scale is a tool designed by PA Yeoman's in the context of Keyline design: a methodology created for the planning of water resources in agricultural soils which, based on the morphology of the site, allows the identification of particular lines and points of the soil where the water can be easily collected, collected and distributed.

In the field of design, the permanence scale indicates the priority with which it is appropriate to consider the elements of the system, on the basis of their relative "permanence" or influence ability, therefore of the energy that must be invested for the modification / structuring / configuration of those elements.

In the image that illustrates the scale of permanence of Yeomans, it appears that the climate is certainly the least influenced factor (or the most permanent one), or in any case something that can vary in the very long period, actually representing something stable and fixed in the context of the design of a site.

In second place we find the morphology of the place: shapes, slopes, hills and valleys are also quite immutable factors, unless you invest huge amounts of energy.

From the third onwards there are elements on which the possibilities of intervention become more significant, in relation to the cost / benefit ratio. Water is the first among these, since it is something governed by nature that man can direct, channel, facilitate on the basis of the morphology of the place.



Yeomans' permanence scale representation (from O. Hablutzel).

Scale Of Permanence

Permanence scale suggests that we look at the water as the primary factor on the basis of which to set the structure of a site. Water flows, digs, moves, fills according to its nature and with such force that it is not always possible to govern it.

For this reason, it is better to fully understand what the dynamics and hydro-geo-morphological processes of a site are, so that the best intervention methods can be identified which, on the one hand, can avoid damage to property (e.g. infrastructure, soil), on the other favour the best use of this natural flow within the site.

The next point on the permanence ladder consists of roads and entrances. This element is one of the firm points of the project, which may require considerable initial investments (both for the construction from scratch and in the event of a rearrangement), which depends strictly on the morphology of the place. The viability of a site must be thought downstream of the study of the water because of the remarkable interaction between the two elements: if we make sure that the flow of the water can be facilitated and directed by the same presence of the roads, we can perform more functions with a single element (and in the event of a new construction or reformulation of the road structure, with the same intervention we achieve several objectives). Otherwise, the road network may be subject to erosion and degradation phenomena by water flow.

By way of example, a road that runs close to the contour lines, if equipped with a special lateral channel, can constitute a vehicle for the collection and conveyance of surface water. A road arranged along the line of maximum slope can itself become a sliding channel during rainy events, suffering the erosion phenomena for which frequent maintenance interventions will be necessary.

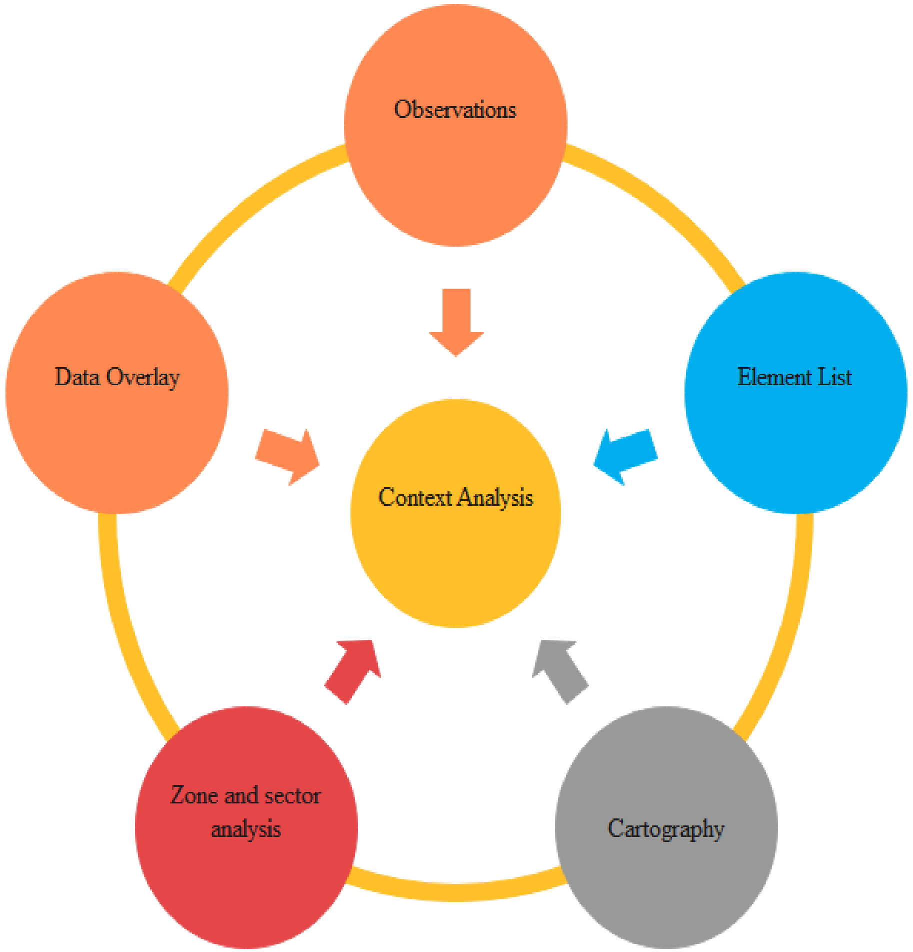
Scale Of Permanence

After the roads we meet trees or woods or complex vegetation systems. These are perennial vegetation systems, whose investment must be made at the beginning for the planting and support of the early years, but which then go on their own, effectively constituting ecosystems.
The time scale in which it is possible to create or modify a wooded system, for which it is necessary to interact with the times and balances of nature, is certainly higher than that necessary to do the same thing on buildings and infrastructures, which are works managed by man almost entirely.

The correct positioning of a building on a site can only take place after having reasoned on the elements described above, on the basis of the relationships that the building will have with them. Thus, a construction can benefit from the wind protection that can be given by the forest, from a climatically or panoramically advantageous exposure, or it can be a point for collecting water, etc.
Once the infrastructures are established, the remaining elements are simpler to manage and modify, also requiring smaller investments whose results are achievable in the short-medium term.
These are the subdivision fences of the different areas of a place, such as vegetable gardens, grazing areas, orchards and so on. The fences can be made in various ways; they can be fixed and mobile according to the management methods of the areas and the protection needs.

The soil is at the last place of the permanence scale, because in a reasonably short time (an arc of about 5 years) it is possible to change its state for the benefit of fertility. For this reason, it seems that in the context of a large project, the identification of interventions on the soil can be done in a non-priority way, based on the use of spaces and crop objectives.
The permanence scale proposed by Yeomans was subsequently integrated by other authors, in consideration of other elements that can be included in the design.

Context analysis



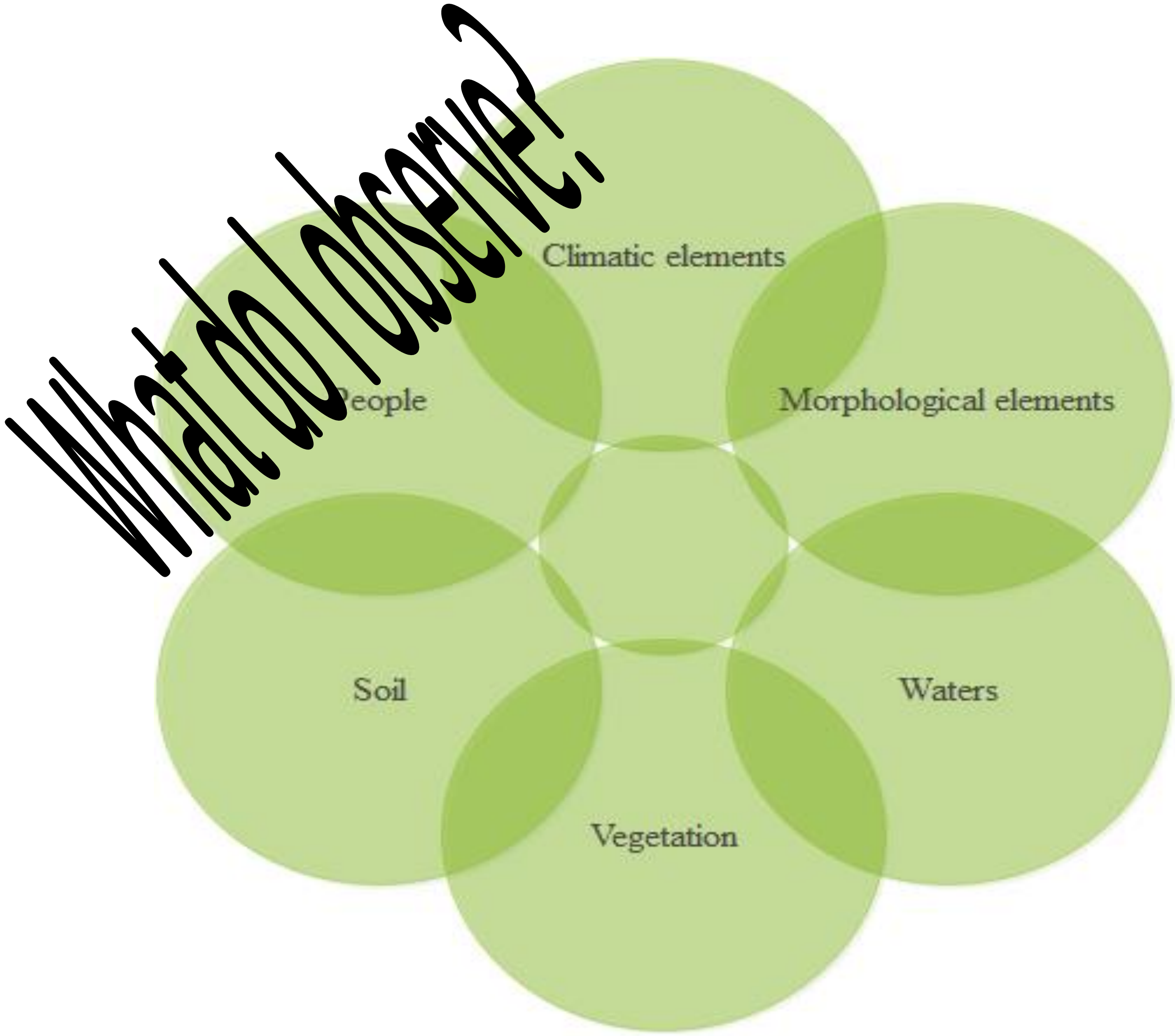
Context analysis – Observation and deduction from nature

Permaculture originates from observation of nature. Much of the learning is based on observation, observing what is happening in the world outside and within us. Through observation we are also able to deduce what are the great mechanisms of functioning of things, such as causes and conditions, change, etc.

Observation is an indispensable tool for permaculture design, probably the one that certainly cannot be done without.

It is not possible to design without having been at least once in the field, since any map, text or description of others cannot replace what the designer can grasp directly on the site. From observation, elements and strategies for design can emerge.

When you are on the site, there are many things to observe. Depending on the project objectives, the context and the time available, it is possible to proceed through a free observation, or a thematic observation.
Free observation allows us to wander around the place, in a relaxed way, and collect a series of elements, letting our attention be captured by the objects of the senses that most affect us, and that questions arise spontaneously, such as: "I wonder because this plant is found only in some areas of the soil ...”



Context analysis – Observation and deduction from nature

The thematic observation focuses on some aspects of the place, some of which are listed below.

Climatic elements: they concern the exposure of the site to atmospheric agents, the trajectory of the Sun and the presence of elements that obstruct it (e.g. large trees, mountain reliefs, ...), areas with particular microclimates (e.g. a torrent shaded by vegetation where it's cool even in summer, or points particularly exposed to the wind). Physical perceptions of the microclimatic conditions of the place can suggest design strategies (e.g. you can imagine making a mushroom farm along the banks of the always wet and cool stream rather than creating an umbrella in an area more exposed to the Sun, or you can take advantage of it the cooler microclimate present in a pine forest to start planting a food forest rather than starting from an Ampelodesmos).

Morphological elements: the slopes and the presence of flat areas help us to imagine where we can place the elements of our project, such as the different types of crops, structures, walkways, etc.

Waters: observing the movements of the water, also through the signs it leaves as it passes (canals, erosion pits, etc.) is of fundamental importance for the design of the entire structure of the site. In particular, it is very useful to observe the water during rainy events: if equipped with boots and raincoat we take a tour of the place during a downpour we will have the opportunity to find out for example where and how to place tanks or basins for collecting rainwater.

Vegetation: the vegetation present on a site and the way it is organized provides a great deal of information on the climate, water, soil, natural and non-natural processes that are ongoing on the site and which also involve other life forms.

Soil: the presence of a sandy or clayey soil, the fact that it is "soft" or "hard" is the basis of the agricultural and structural design of a site.

People: a good designer will make sure to design considering what are the human aspects of a site, so that the project is perfectly integrated into the social reality. By observing the people who will manage the site (they may be the clients, or themselves if it is their own project) and also the wider context (e.g. neighborhood), the designer will have the elements to design a system that beyond to function economically and environmentally, be sustainable in the long term for those who manage it.

Context analysis – Observation and deduction from nature

How do I use what I observed in the design?

Recalling that the goal of PC design is to create a sustainable human system in all respects, observation allows us to work in consideration of the real characteristics of the place, therefore to formulate suitable strategies and solutions (e.g. if I have observed that in a site at an altitude of 550 m asl there are few orange trees that struggle to grow and bear fruit, I could immediately discard the idea of planting a citrus grove).

The observation suggests strategies and solutions: for example if I observe the presence of numerous aromatic plants that spontaneously grow on a site, I can work on the idea of planting a cultivation of aromatic herbs for the production of spices, being reasonably sure that the place will help me . It is a matter of "feeling the vocation of the place".

Observation allows me to see what resources are available on the site that can support the solutions and design strategies that the designer formulates (e.g. the presence of a deciduous grove provides a quantity of mulch).

From observation to deduction

Observation is a non-conceptual work, a recording of "what I see and hear" that allows you to create a sort of database.

From this follows a conceptual activity that tries to put together the collected pieces, to respond to the various "why does this happen?" and "why is that there?"

If some answers can be given by prolonged observation, we can find others from other sources, thanks to those who before us collected other data or asked our own or similar questions.

Then follows a deduction from nature, an understanding of the mechanisms that nature puts in place for life and that I can use as a strategy for the benefit of my system.

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Context analysis – Observation and deduction from nature

Here is an example of how this process can work:

In a site where there is an olive grove, I observe that the vast majority of the spontaneous hawthorn plants are born right under the olive trees. If, in addition to complaining about the fact that I have to eradicate them every year, I ask myself "Why exactly do they grow under the olive trees?", I can do research on the reproduction of the hawthorn, or ask a botanical expert, and find that the hawthorn propagates mainly thanks to birds, which are ingesting the berries and thus releasing the seeds in guano in the places where they have the opportunity to stop. In this case the olive trees are their favourite resting place in an environment where the rest of the vegetation is made up of herbaceous plants and some shrubs.

To benefit my design, I can use what I have learned: I could for example think of placing perches along a strip of land where I would like to create a natural fence with thorny plants, or to speed up the natural reforestation of an area.

Context analysis – Observation and deduction from nature

“Deductions from nature” are fundamental concepts in the curricula of those who deal with plants and nature, which are of particular interest for permaculture design.

Guilds - In nature, the spontaneous association of different species of plants and animals, or mixed groups of species reappearing in a given place can often be observed, taking the name of “guilds”. By looking at the functioning of these associations, one can identify beneficial relationships between the different species that find advantageous staying close to greater the chances of survival and well-being.

A guild is therefore "a harmonious association of species grouped around a central element (plant or animal) and which operates in relation to the latter, favouring its growth, facilitating its management and mitigating adverse environmental effects" (Bill Mollison - Permaculture, Design Manual). There are many examples of guilds in Nature, such as oak forests where many other plant species benefit from the shade of the trees and animals, such as jays, feed on their fruits and promote their propagation.

An example of how the guild concept can be applied in a production system is the association of olive-polling-spawn, where the central element is the olive tree. Asparagus plants love to grow around olive trees, as they have similar ecological-environmental requirements and benefit from their undemanding shade. Both plant species manage to have their ideal conditions to reach production potential on the same surface of land. The presence of the hens does not damage the plants, on the contrary they benefit from the work of weeding, fertilising and cleaning up certain parasites, such as the olive fly, whose larvae and pupae that fall to the ground are attractive to these animals.
Vegetation sequences

If we could leave a place devastated by fire or water completely undisturbed by anthropogenic factors (fires, pastures etc.) and have the opportunity to observe it in the long run, we could notice how it would transform, passing from a simple system with pioneer species before herbaceous, then shrubby, to a system that is gradually more complex with tall vegetation, where the pioneers are disappearing in favour of more lush and productive species (in terms of biomass, fruits, etc.), where there is greater complexity in terms of useful relationships between the living, more resilience. In nature, therefore, a succession of plant and animal species is observed over time.

If this occurs in nature in a long time if compared to a human life, in the design we can take a cue from "what nature would like to do" and create the conditions for this process to take place more quickly.

For example, planting all the different species of the succession at the same time (pioneer, herbaceous cover, undergrowth species, leguminous trees, tree crops, etc.), perhaps using varieties of interest for human use, with careful management, it is possible to have in a few years a production system which in nature would require very long periods.

Tools for analysis

The design process requires actions of knowing, observing, collecting data, all of which will then be analyzed. These actions will lead to the identification of opportunities, to a better management of the project's implementation costs, to the determination of valuable elements, as well as to the identification of the ecological processes from the site.

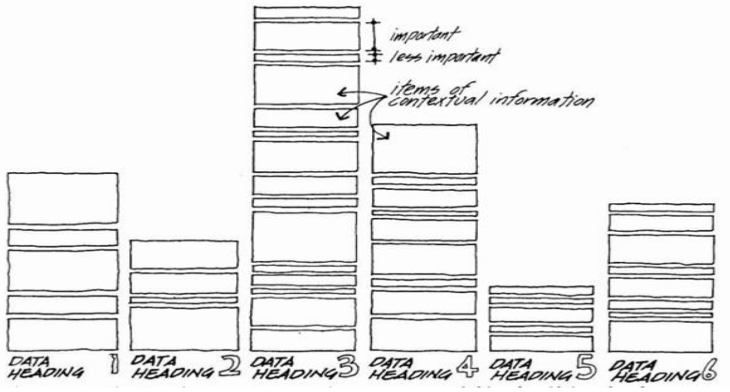
In this context, for the clarification, for the integration and the determination of the phenomena from the site, it is necessary to express the information from the field in graphical forms. (White, 1983).

The advantage of graphically transposing information leads to a better understanding between the different people involved in the entire design process. Phenomena, actions, dysfunctions or valuable points are expressed in characteristic forms, through the graphic dialogue. The graphic expression facilitates the integration of the future proposals, but also the solution of the problems identified on the site (LaGro, 2001). But until we reach the site analysis stage, the first step to be taken is to know the terrain. Site inspection familiarizes us with the relationships and actions from the field. And to be able to deepen the knowledge of the area we need some tools. Data collection in written or drawn form is done with the help of sketches, topographic plans, block diagrams and photographs. The symbols and other graphic elements we use help us define the character of the site, the spatial organization of the elements and then their articulation in a future proposal. (LaGro, 2001). The graphic forms used in expressing and transmitting messages are accessible and easily understood by all.

Therefore, the graphics used must be legible and understandable to everyone, easily accessible, so that it does not give way to different interpretations, taking into account that people from various fields can participate in the analysis and in the project as such and that the project will then be presented to the beneficiaries. Understanding the site with the help of graphics leads to finding a common language.

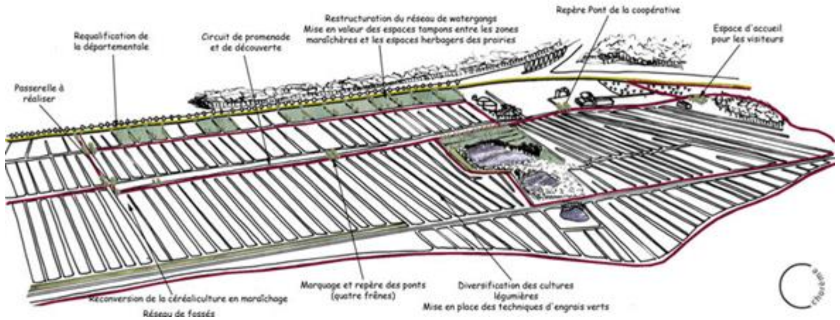
Tools for analysis

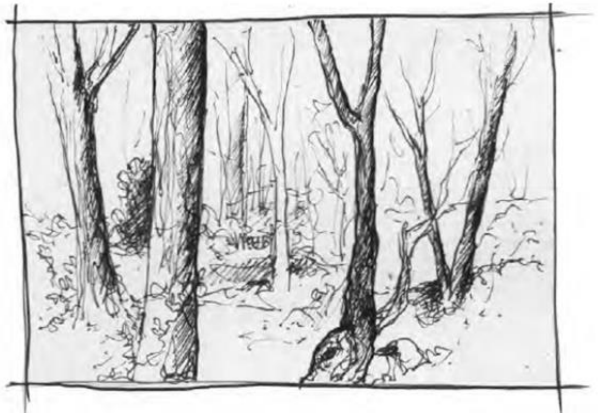
The project preparation will start with site visits, when people will take a look at aerial photos - a good tool that is within reach of anyone is Google Earth, often the site can provide us with an evolution of the site in images of the terrain. Studies in related fields can also be useful, as well as browsing websites that can provide various types of important information, documentary sources, monographs, technical files, technical documentation, and archives. All these sources can be used according to the type of project and according to its degree of complexity. It is useful to classify the information in order to have a hierarchy of the types of relations between elements, expressed in a concise and legible way by means of fields that may contain keywords or even text. Professor Edward T. White (1983) proposes such an organization of thought and an ordering according to certain attributes of the information collected from the site.



Organization of information, source Edward T. White

<u>Quick sketches</u> can be the basis for easier representation of the system of relationships in the field. The degree of detail and the graphic expression are maintained at a general level, because a larger scale of detailing can lead to the proposal being inflexible (we risk not having the possibility to modify future proposals).





Landscape block diagram, source https://www.choreme.fr/fr/portfolio/le-marais-audomarois/

Sketches, source *http://www.lot.gouv.fr/IMG/pdf/95072_eie_voirie_rocamadour_46_vf_p_cinq.pdf*

Tools for analysis

Landscape block diagram completes the classic representation (mapping) of the territory, coming with information and giving greater coherence to the graphic expression. The block diagram as a tool for the analysis of a territory is much more explicit in relation to a map and can better clarify certain problems of the territory (CETE Nord-Picardie, 2001). It is a tool traditionally used in geology, geography or even industrial engineering (Fajon, 2008). It should be noted that this tool is generally used for projects that are carried out on larger areas, but we can also adapt the technique for smaller sites, when we want to highlight certain attributes. The technique of representing a block-diagram is that of perspective rendering, by synthesizing the site. The elements characteristic to a certain type of landscape are highlighted, pointing to the landscape units (CETE Nord-Picardie, 2001) or the main areas of a future project are exploited.

If aerial photographs are tools with an exhaustive value of information about a territory (they do not provide us with a hierarchy or interpretation of the elements of the site), and the other tools used for representation (sketches etc.) capture images in general at the level of the human eye; block diagrams highlight the territory in oblique aerial perspective. Thus, the relief forms are represented, offering the opportunity for a selective image of the site (CETE Nord-Picardie, 2001). The relief forms come to complete the visual dialogue by transmitting information in three dimensions. The block diagram is an attractive way of representing and simplifying an understanding of a real framework, emphasizing the power lines, the strengths of the site and its specificity (Fajon, 2008).

A block diagram can be *read* in three ways: a simple reading of the site representation without being accompanied by the text that would complete the information. This is the level of simple graphical representation that highlights the direct perception, exploiting the sensitivity of the viewers (Fajon, 2008). The second form of representation is the one accompanied by a synthetic text that lets the sensitivity take priority. The third level of representation is that of *the scientific text*, in which each graphic form in the block diagram is accompanied by explanations. The text is longer, the explanations are meant to enrich the graphic picture through critical analysis (Fajon, 2008). The way of representing a block diagram can be:

- ✔ manual
- ✔ using 3D rendering software.

But what is important is not so much how to make a block diagram, but rather the synthetic introduction of information from the site.

Tools for analysis

Photography is a landscape analysis tool. Intervention on photography is a means of visual communication, photography being a form of "specific and heterogeneous language" (Joly, 2001). Through the photo, a message is transmitted, which the viewer decrypts. Thus, by analyzing the photographs we can choose a series of elements that highlight the site or do the contrary. Through the study of photography, we can figure out the succession of plans, the favourable or less favourable angles of a site, or the wide openings of perspective.

To go further - Bibliography

Books and articles

CETE Nord-Picardie, 2001, *Bloc-diagramme paysager : un outil d'analyse spatiale pour l'aménagement du territoire,* Note d'Information - Économie Environnement Conception - Série(EEC) no. 66, p.6 Cerema, https://www.cerema.fr

Fajon Philippe, 2008, *Le bloc-diagramme : un outil pour modéliser le paysage de façon dynamique?*. Cahier des thèmes transversaux ArScAn, CNRS - UMR 7041 (Archéologie et Sciences de l'Antiquité - ArScAn), VIII, pp.219-223. ⟨hal-02236145⟩

Joly Martine, 2001, *Introduction a l`analyse de l`image*, ed. Nathan, Paris

LaGro jr. James A., 2001, *Site Analysis: Linking Program and Concept in Land Planning and Design*, ed. John Wiley & Sons, New York

White Edward T., 1983, *Site analysis. Diagramming information for architectural design*, ed. Architectural Media, Florida

Websites

https://www.banquedesterritoires.fr/representation-et-interpretation-du-paysage-outils-pour-observer-analyser-valoriser-ministere

https://www.choreme.fr/fr/

http://www.lot.gouv.fr/IMG/pdf/95072_eie_voirie_rocamadour_46_vf_p_cinq.pdf

Tools for analysis – Elements/Vegetation inventory

The inventory is a collection of information needed to describe and determine the characteristics of an element / terrain. The collected information will be the basis for further analysis. In the process of identifying and analysing the elements of the site, a first step is the preparation of a plan, a map or a schema of the site that we wish to inventory (Steiner, 2008). The format of the map we work on may vary depending on the area we have to research. Very important are also the specifications of the map we work with. The north, the scale, the legend with the information, the name of the map will all be specified on the map (Steiner, 2008). We will need to pinpoint objects in the field using aerial photographs and field visits.

The vegetation is an important element in any project that includes landscaping. In the first phase of the inventory, we will locate the plant units using aerial photographs and information used by software such as Google Earth. The density and diversity of the plant units will be checked later in the field, after their positioning on the map. Maps with plant formations (community plants) which include their description and species composition (Murphy, 2005) are most often preferred. In the inventory of vegetation, the main plant communities will include information on the vegetal typologies on vegetation floors, on location (geographical positioning), on dominant species or on natural and anthropic areas. This is when you can identify native plants and species introduced in the area.

After identifying the plants, the vegetation inventory may include inventory files that specify more detailed information about:

Genus, Species, Age, Height (by ground calculation methods), Identification of number; single or mass (if we speak of woody vegetation)

Ecological requirements, Edaphic conditions

In the case of the tree inventory, we must also take into consideration:

- The size of the tree and the width of the crown
- The health of the tree (roots, trunk, branches, leaves)
- The position of the tree (use and aesthetic value) (LaGro, 2001).

Tools for analysis

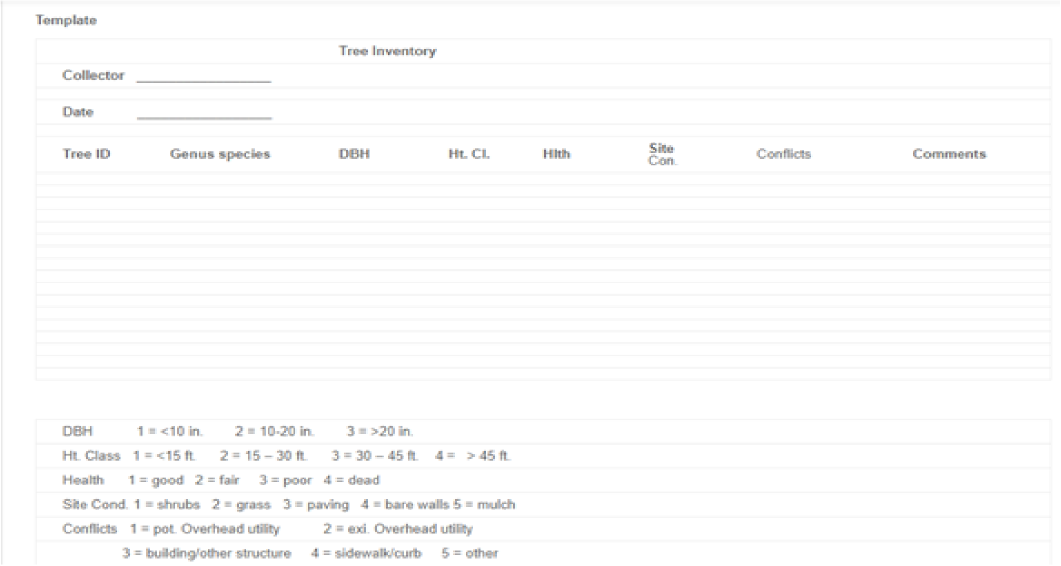
Other indications are also possible; for example, if the identified species is listed in different lists as threatened species, invasive species, etc. (Murphy, 2005).

List of vegetation inventory: (according to Steiner, 2008)

1. Plant associations and communities
2. Vegetation units
3. List of species
4. Composition and distribution of species
5. Ecoton and edge profile
6. Rare species, endangered and threatened
7. Invasive species

The inventory can also include lists and specifications about the seasonal influences of plants on the aesthetic image of the site (Murphy, 2005). In other words, the ambience they create and the type of decoration throughout the year. Detailed inventory files can be established with information on how to decorate and the season when it takes place and we can talk about decoration through flowers, stems and shoots, fruits or seeds.

- Example of Tree Inventory File


Template

Tree Inventory

Collector ______________

Date ______________

Tree ID	Genus species	DBH	Ht. Cl.	Hlth	Site Con.	Conflicts	Comments

DBH 1 = <10 in. 2 = 10-20 in. 3 = >20 in.
Ht. Class 1 = <15 ft. 2 = 15 – 30 ft. 3 = 30 – 45 ft. 4 = > 45 ft.
Health 1 = good 2 = fair 3 = poor 4 = dead
Site Cond. 1 = shrubs 2 = grass 3 = paving 4 = bare walls 5 = mulch
Conflicts 1 = pot. Overhead utility 2 = exi. Overhead utility
3 = building/other structure 4 = sidewalk/curb 5 = other

Template, source https://ufmptoolkit.net/two/inventories-assessments/#inventories-vegetation

Tools for analysis

Example of Inventory Matrix

Tree Sheet Inventory

Collector ______________________

Date 10/10/2012

DBH 1 = <10 in. 2 = 10-20 in. 3 = >20 in.
Ht. Class 1 = <15 ft. 2 = 15 - 30 ft. 3 = 30 - 45 ft. 4 = >45 ft.
Health 1 = good 2 = fair 3 = poor 4 = dead
Site Cond. 1 = shrubs 2 = grass 3 = paving 4 = bare walls 5 = mulch
Conflicts 1 = pot. Overhead utility 2 = exi. Overhead utility 3 = building/other structure 4 = sidewalk/curb 5 = other

Tree ID	Genus species	DBH	Ht. Cl.	Hlth	Site Con	Conflicts	Comments
WP 67	*Fraxinus uhdei*	26"	4				note: Shamel Ash is known for root damage/poor structure
WP 68	*Chitalpa taskentensis*	5"	1	2	5		N:33, 58', 51.6" W: 117, 23' 21.1" Codominant with Included Bark
WP 69	*Quercus agrifolia*	5"	1	1	5		
WP 70	*Chitalpa taskentensis*	4"	1	1	5		N:33, 58', 51.3" W: 117, 23', 20.3" Suckers need to be trimmed.
WP 71	*Parkinsonia "Desert Museum"*	17"	2	1	5		Hybrid Palo Verde Crossing/ touching branches
WP 72	*Arbutus 'Marina'*	7"	1	1	5		Multi
WP 73	*Prunus dulcis 'All in one'*	6"	1	1	5		Almond. Multi- grafted at 1'/2'
WP 74	*Sapote*	7"					Multi- stemmed
WP 75	*Prunus dulcis almendro "Garden Prince"*	3"	1	1	5		Almond, Multi
WP 76	*Pyrus pyrifolia*	3"	1	1	5		Asian Pear
WP 77	*Plum-?*	3"	1	1	5		Sucker at bottom
WP 78	*Prunus persica*	8"	1	1	5		California curl leaf Peach
WP 79	*Tabebuia impetiginosa*	2"	2	1	5		remove and replant
WP 80	*Tabebuia Impetiginosa*	1"	2	1	5		remove and replant
WP 81	?	2"	1	2			
WP 82	*Geijera parviflora*	5"	1	1	5		Australian willow
WP 83	*Geijera parviflora*	2"	1	1	5		

Tree Sheet Inventory, source *https://ufmptoolkit.net/two/inventories-assessments/#inventories-vegetation*

- Example of Inventory and Assessement

Inventories & Assessments, source *https://ufmptoolkit.net/two/inventories-assessments/#inventories-vegetation*

Tools for analysis

To go further - Bibliography

1. LaGro jr. James A., 2001, Site Analysis: Linking Program and Concept in Land Planning and Design, John Wiley & Sons, New York, 1 edition
2. Larcher Jean-Luc, Gelgon Thierry, 2012, *Aménagement des espaces verts urbains et du paysage rural*, Lavoisier, Paris, 4th ed.
3. Murphy Michael D., 2005, *Landscape Architecture Theory. An Evolving Body of Thought*, WavelandPress, LongGrove, Illinois
4. Steiner, Frederick R. 2008, *The living landscape: an ecological approach to landscape planning*, Island Press, Washington, 2nd ed.

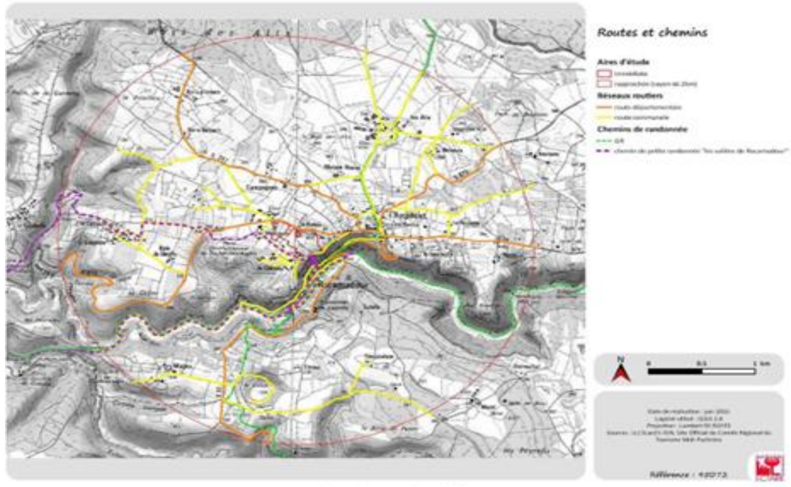
Websites

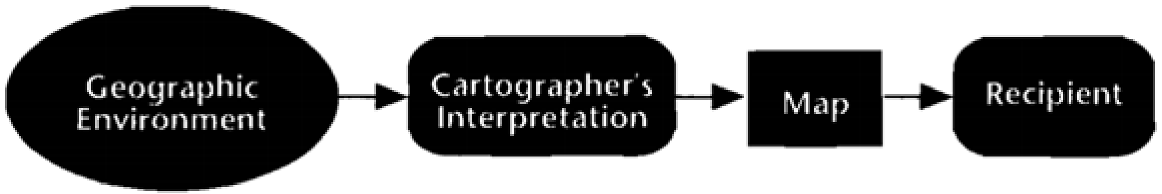
1. https://korykreiseder.weebly.com/context-site-inventory-and-site-analysis.html#
2. https://ufmptoolkit.net/two/inventories-assessments/#inventories-vegetation

Tools for analysis – Cartography and mapping

When we talk about mapping, we refer to the representation in graphic form, as specified by Alan M. MacEachren in the introduction of the book *How maps work. Representation, Visualization and Design* (MacEachren, 2004). He defines cartography as *the creation and study of maps in all their forms*. That is why mapping can be seen as an efficient way to use, analyze and interpret the different signs and forms and to put them in relation to each other in two dimensions.

Mapping has become an easy means of communication by accurately interpreting data and rendering them in an easily interpretable form. Communication is the main function of cartography, and the map is the vector of communication. When designing, we will translate the information from the site into explicit and comprehensible graphic forms using different types of tools.





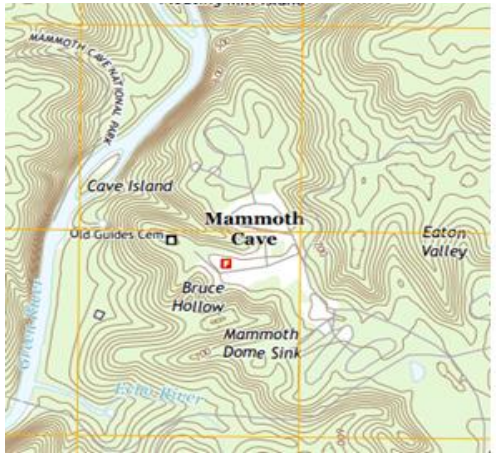
A schematic depiction of cartography as a process of information communication, (Source: Alan MacEachren (2004). *How maps work. Representation, Visualization and Design)*

Example of map (Source [http://www.lot.gouv.fr/IMG/pdf/95072_eie_voirie_rocamadour_46_vf_p_cinq.pdf)](http://www.lot.gouv.fr/IMG/pdf/95072_eie_voirie_rocamadour_46_vf_p_cinq.pdf)

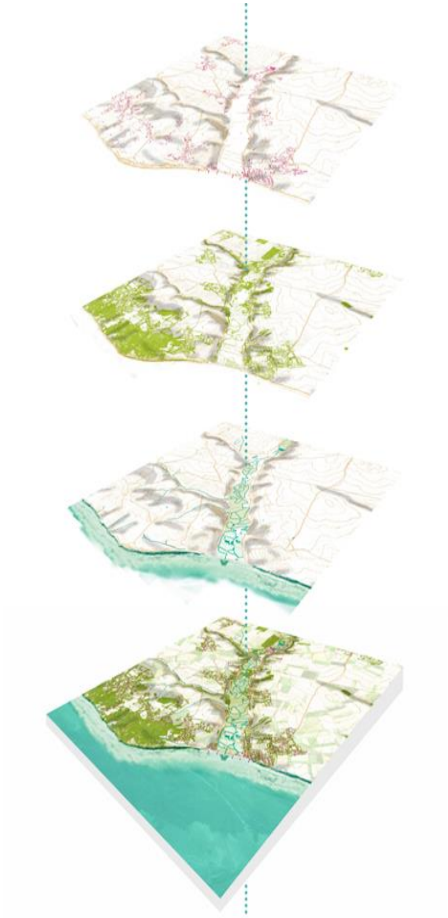
One of these is the map, which represents a tool that summarizes the information from a terrain that will later be rendered by a graphical representation with geographical references. In this way, we obtain knowledge about distances, cardinal points, geographical position, typologies of relief (LaGro, 2001)One of these is the map, which represents a tool that summarizes the information from a terrain that will later be rendered by a graphical representation with geographical references. In this way, we obtain knowledge about distances, cardinal points, geographical position, typologies of relief (LaGro, 2001).

Tools for analysis – Cartography and mapping

Maps can convey information about the physical environment, the biological environment, landscapes and indicate the relationships that are established between the different elements of a site (LaGro, 2001). For the most part, maps are interpreted as objects that convey predefined messages. Three essential attributes are needed for mapping: the scale, the position and the symbols (LaGro, 2001, Monmonier, 1996), so the information can be used correctly.
Each map is a graphical representation of a territory in a more detailed form (if the scale of representation is smaller) or in a simplistic form (if the scale of representation of the territory is large).



The representation of maps https://geology.com/maps/types-of-maps/#topographic-maps.
https://www.openstreetmap.org/#map=14/48.8638/2.2417



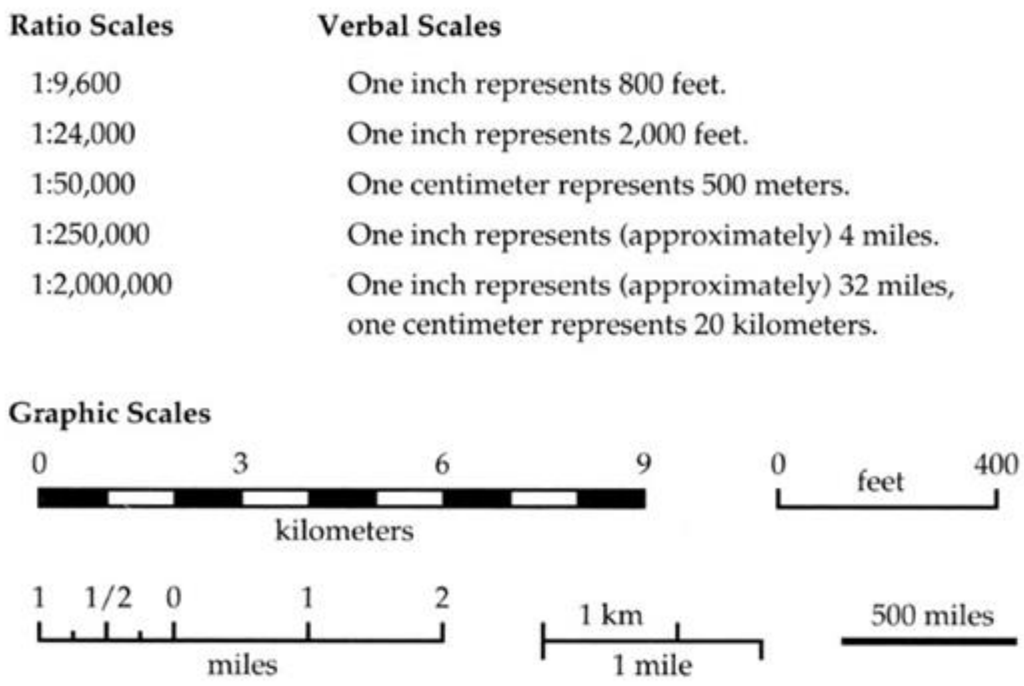
Different types of maps used in projects, source
https://www.choreme.fr/fr/portfolio/projet-territorial-de-la-basse-vallee-de-la-saane/

The representation scale is represented by the ratio between the size shown on the map and the size/distance on the ground (the real one). In order to accurately render information from the field, the scale of the map is of great importance (LaGro, 2001). The representation scale expresses the distances from the plan and the distances from reality in three ways: as a ratio, as a short sentence, or in graphic form (Monmonier, 1996).

A full-size drawing would be on a scale of 1: 1 or 1/1, while a half-size drawing of the real size would be done using the ratio of 1: 2 or 1/2 (Waterman, 2009). The numerical expression between the dimension in the drawing and the one in reality is explained as follows: the higher the ratio expressed, the smaller the scale of representation. The scale of a plan can be interpreted as an equation, converting the ratio specified in the plan.

1:1	Actual size
1:10	Bus shelter
1:100	Garden
1:500	City park
1:1,000	Neighbourhood
1:20,000	City
1:200,000	County
1:1,000,000	Country
1:5,000,000	Europe
1:50,000,000	World

Different types scale, source The fundamentals of landscape architecture, Tim Waterman, 2009



Different types of representation scale How to lie with maps Mark S. Monmonier 2018.

Each map is a graphical representation of a territory in a more detailed form (if the scale of representation is smaller) or in a simplistic form (if the scale of representation of the territory is large).

For example, in the case of the ratio of 1: 10,000, 1 cm measured in the plan or on the map represents 10,000 cm in reality, in other words 1 cm measured on the plan represents 100 m in reality (LaGro, 2001). The verbal expression of the ratio is expressed as follows: one centimetre represents 100 meters. The third form, called the Graphic Scale, is one of the more accurate and accessible means of communication when it comes to maps.The graphical scale can also be used when the map is reduced or enlarged, maintaining the possibility of finding the correct size of the distances (Monmonier, 2018).

The basics of a project : What is the actual support for our work?

In order to design a project, a few steps are essential to be able to represent all the features. The transposition through a horizontal drawing measured in two dimensions is called plan. The plan places the viewer in an imaginary position above the site or object looking straight down, without any distortion (Waterman, 2009). **The plan** gives us a horizontal image of a surface and a representation of the distances between the objects encountered in the field. Plans are essential to ensure that the design proposals are properly proportioned, framing the site in the established manner (Waterman, 2009).

Garden plan, source *http://landezine.com/index.php/2013/04/garden-in-comporta-by-topiaris-landscape-architecture/*

If the plan represents the horizontal view allowing people to see the terrain from above, the section is understood as a vertical view through a terrain or an object. The section is made by an imaginary line that runs along the horizontal plane.

The section does not reproduce the depth or perspective of a field, but strictly expresses the elements that will be on the imaginary line or in its immediate vicinity. Through the section we can see the height and width of each object drawn on a scale, in the horizontal plane. (Waterman, 2009).

Garden section, source http://landezine.com/index.php/2013/04/garden-in-comporta-by-topiaris-landscape-architecture/

To go further - Bibliography

1. LaGro jr. James A., 2001, *Site Analysis: Linking Program and Concept in Land Planning and Design,* John Wiley & Sons, New York, 1 edition,

2. MacEachren Alan M., 2004, *How maps work. Representation, Visualization and Design*, The Guiford Press, New York

3. Monmonier, Mark S., 2018, *How to lie with maps*, The University of Chicago Press, Chicago, 3th ed.

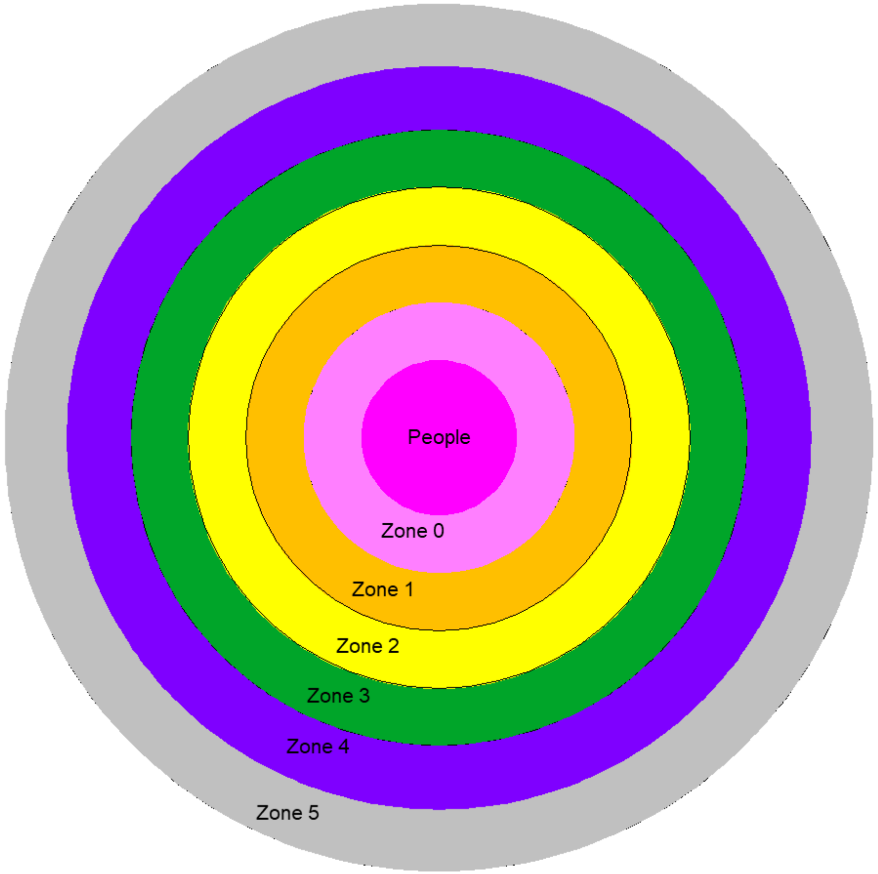
4. Waterman Tim, 2009, The fundamentals of landscape architecture, AVA Publishing, Lausanne.

Websites

1. https://www.choreme.fr/fr/portfolio/projet-territorial-de-la-basse-vallee-de-la-saane/
2. https://geology.com/maps/types-of-maps/#topographic-maps
3. http://landezine.com/index.php/2013/04
4. http://www.lot.gouv.fr/IMG/pdf/95072_eie_voirie_rocamadour_46_vf_p_cinq.pdf
5. https://www.openstreetmap.org/#map=14/48.8638/2.2417

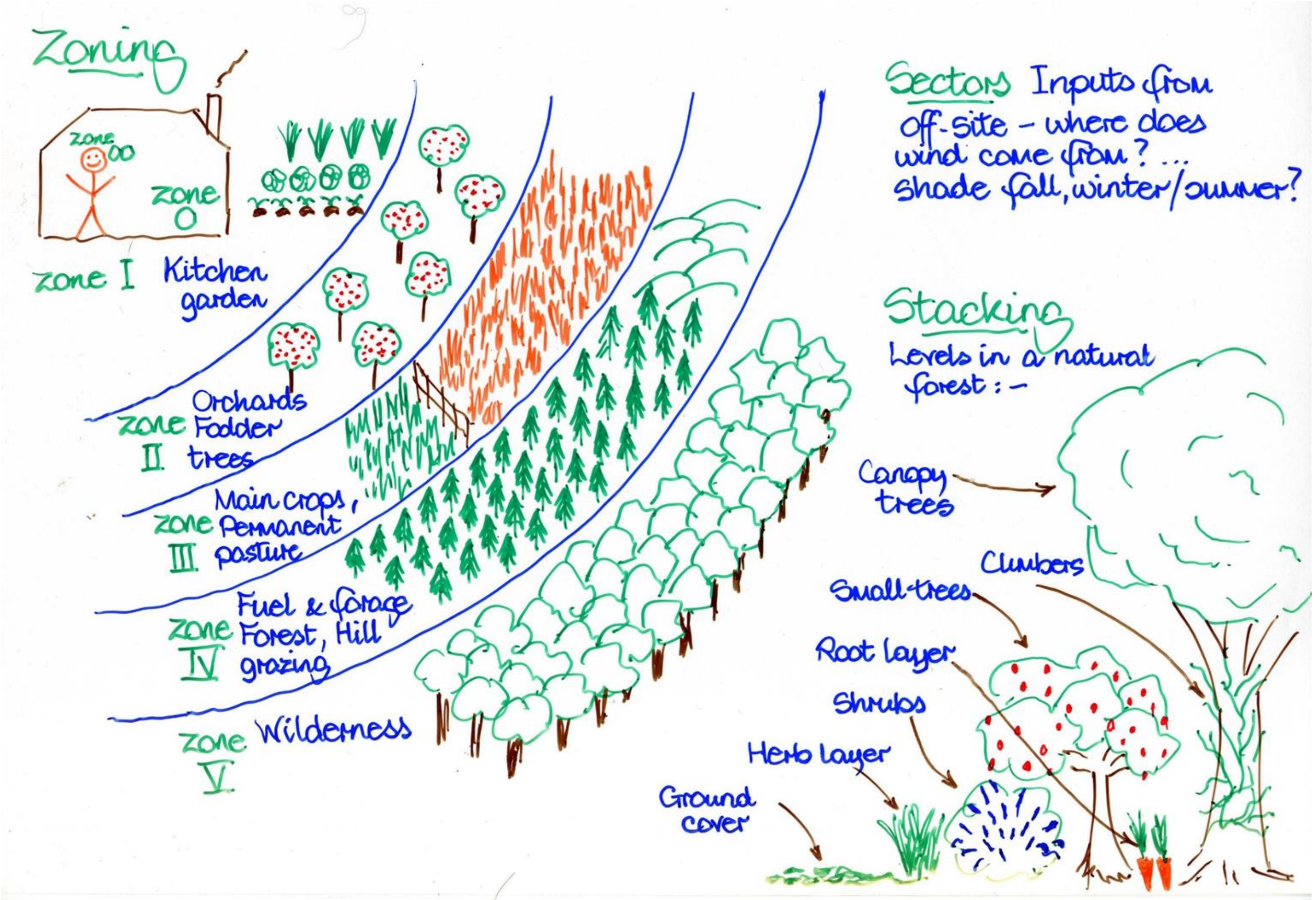
Tools for analysis – Zone, elevation and sectors plan

The zone are identified on the basis of the energy available on site, in terms of presence, labor, waste materials, food, etc.
Typically the areas are identified as a series of concentric areas that have the center in what is the heart of the site, normally the home or structure where the main human activities take place. As we move away from the center, human activities decrease, to leave room for the activities naturally conducted by the system itself.



Zone 00 (centre): the individual or group of individuals responsible for the design / management of the system
Zone 0: the part of the system in which the activities are most intensely carried out - the house, the shed, the transformation laboratory, etc.
Zone I: intensive vegetable garden, irrigated garden, home aromatic herbs
Zone II: irrigated orchard, vegetable garden, small animals
Zone III: main crops not irrigated, pastures, large animals
Zone IV: uncultivated land, forests, wetlands (controlled anyway)
Zone V: wild territory in its natural state

Zone, elevation and sectors plan



Zone, elevation and sectors plan

This type of representation serves to orient us when we find ourselves defining the structure of a site.

Zone 00 not originally present in the permaculture literature, has been inserted because the importance of considering the human element in the design of the systems has been recognized, so that they can be based on the reality of specific individuals, therefore be sustainable for those who manage them.

Zone 0 is the mainly lived one, in which the human presence is practically constant in the time of use of the system and most of the energy is invested. Generally, it is the home or the main structure of the site, so here there are elements such as pergolas, small greenhouses, potted plants, water points, canopies, warehouses for everyday tools.

In this area the water and energy systems are concentrated, so the design will be mainly oriented towards the air conditioning of the rooms, the energy and water self-sufficiency, and the identification of the material and energy flows at the input and output for their recovery / reuse for other purposes (e.g. purification or reuse of waste water for irrigation of fruit trees near the house).

Zone I is generally the one closest to zone 0, where human presence is daily. Here you can find small structures and vegetation that use the zone 0, such as pergolas or greenhouses leaning against the wall of the house, or that require daily care, surveillance and maintenance, or that are frequently used.

The design of this area will consider the details of the spaces available with their characteristics (exposure, slopes, etc.), including the flows of people passing through them and the usage habits.

Zone II is the one where there is still a high level of control; there can be fruit trees that need care and irrigation, the vegetable garden, small animals such as chickens and ducks, tool stores or spaces for special processes (squeegees, processing workshops, etc.).

In **zone III** there are crops that do not require daily care, nor in general irrigation. Here we can find arable land, orchards, grazing areas for large animals, water points for livestock or for emergency irrigation, large trees such as walnuts and oaks.

Zone IV is very little cared for being in a semi-wild state, you go for annual maintenance operations (e.g. picking or cutting trees) or for the collection of fruits (e.g. chestnuts, hazelnuts, pine nuts).

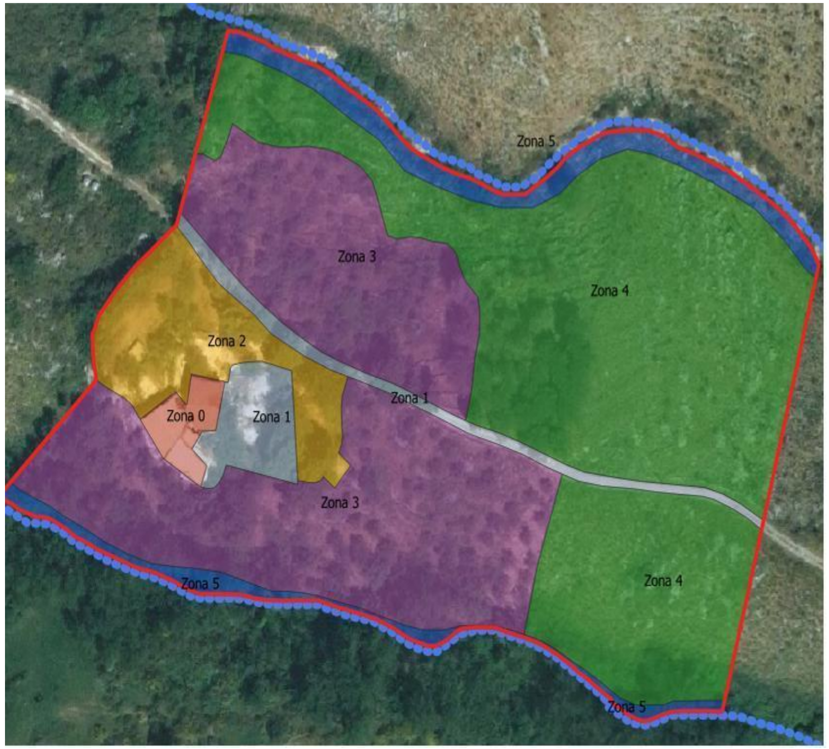
This is the area in which it makes sense to invest energy in the design of a perennial system, such as a food forest, which requires relatively long development times, but which once functioning makes us products of various types (e.g. fruits, fodder, herbs medicines) only at the cost of collection.

Zone V is absolutely untouched, or sees only very slight human interventions. It is the space where nature works as it wishes, where there is no design, where you can go to learn, find ideas and inspiration.

Zone, elevation and sectors plan

Not in all cases the graphical representation of the areas will be in concentric circles, but the shape and size of the areas vary according to the morphology of the site and the people who design and manage the system. The following image illustrates an example.

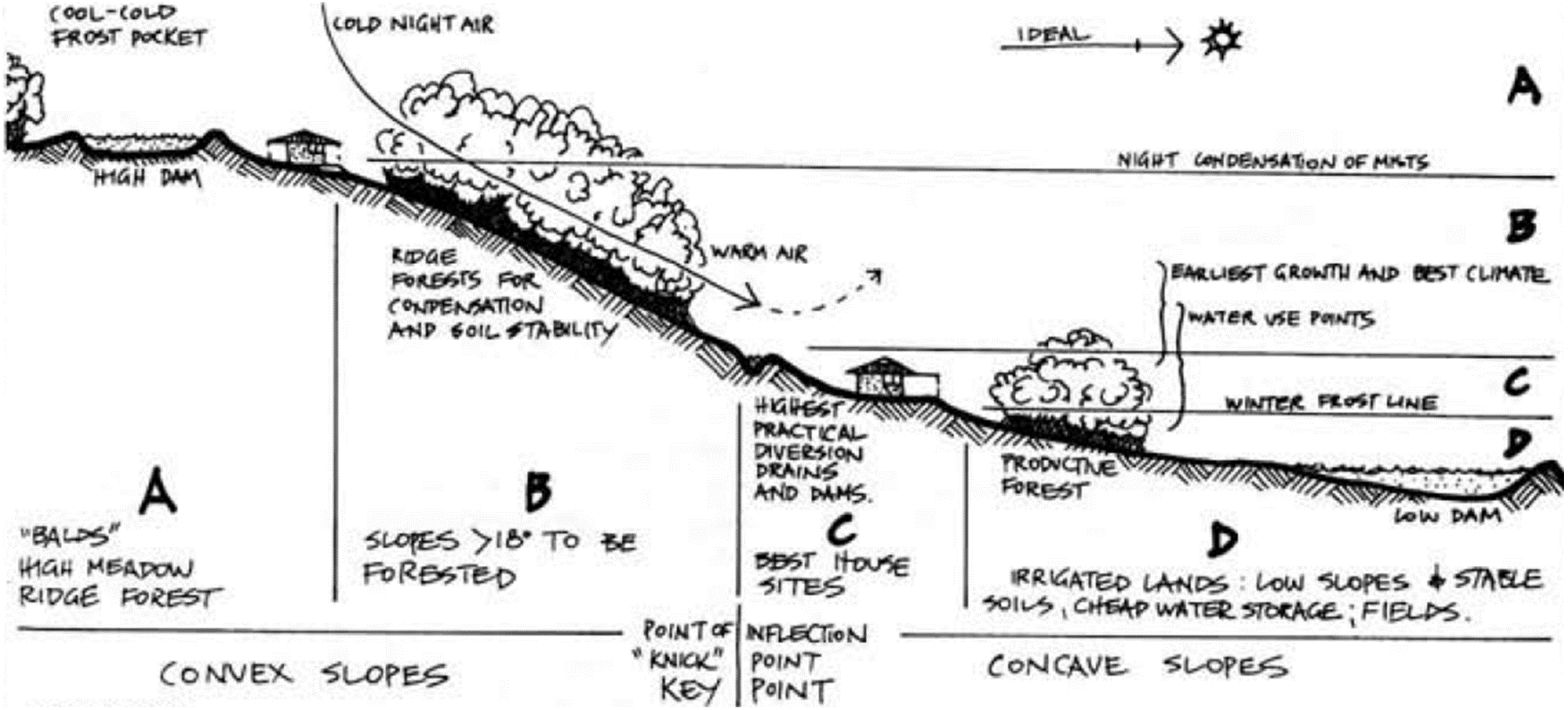
The morphology of the site is decisive for determining the areas and establishing the positioning of some elements.
It is clear that the presence of more or less steep areas can influence the passageways and the frequency of visits to the spaces (due to the energy to be used), and generally the slopes of a terrain can suggest the routes. But in particular, we refer to the water paths, for which it is possible to take advantage of the force of gravity, making it possible to move as much as possible by fall and thus making the system more energy efficient.
For example, if the main source of water was a well, which requires the use of a pump for extraction, it makes sense to place the storage tank upstream of the areas of use (e.g. home and irrigation garden). Just as it makes sense to place a water collection tank at the lowest possible point.



Non concentric zoning in a farm.

In this regard, it is possible to resort to the use of works such as barriers, terraces, canals, bumps, drainage systems, and for larger scale systems to key-line design.

Zone, elevation and sectors plan



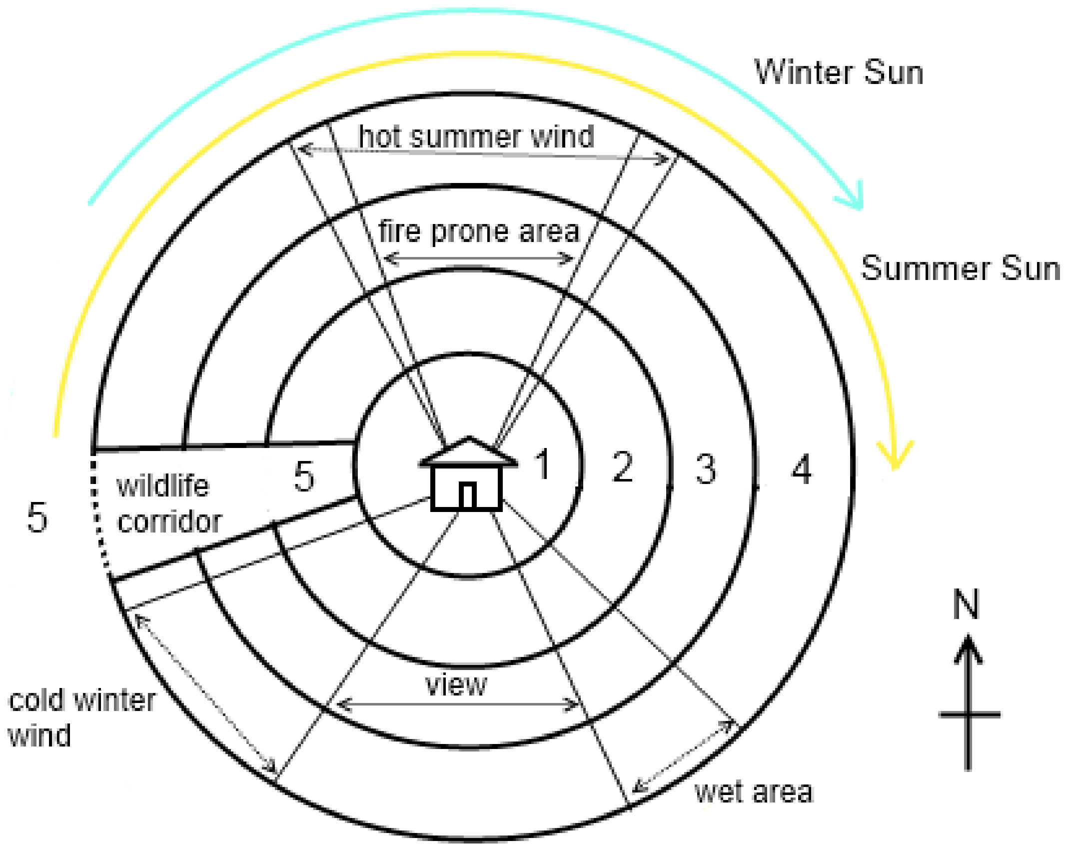
Zone, elevation and sectors plan

Zoning must certainly be crossed with the sectors, the energy flows that pass through the site, to complete the picture of the energy information that allows us to make our design assessments.

The representation of the sectors allows us to visualize the direction from which those naturally present energy flows come, which can be a problem or a resource for the site.

In the sector of the Sun we are going to place photovoltaic panels or a greenhouse for heating the house. In the same way, a windbreak barrier or a wind turbine for energy production can be positioned appropriately to protect the system from the prevailing wind, or to take advantage of it.

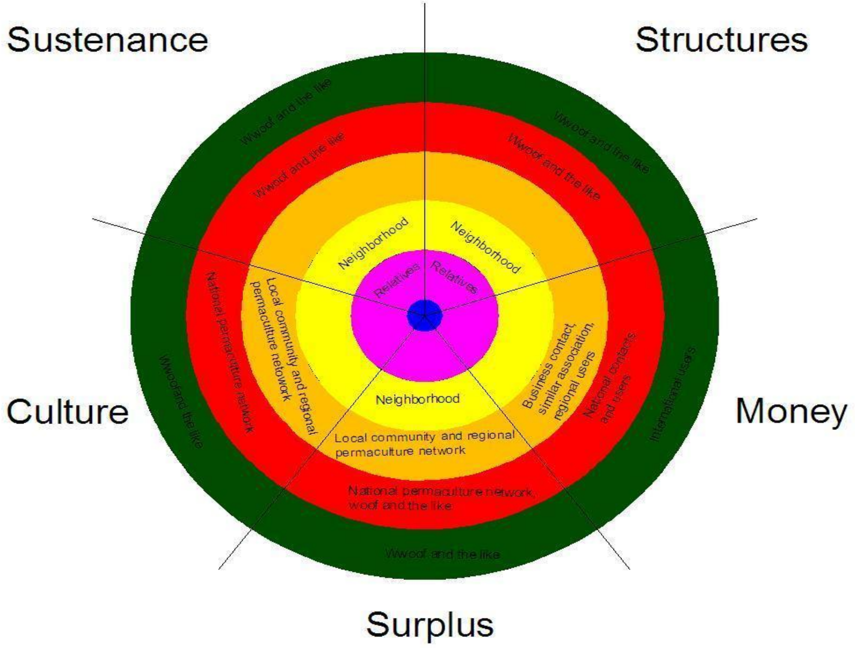
Wildlife also represents a flow of energy which, if properly conveyed, can benefit the system: the project "Il Bosco di Tiola" project at Castello di Serravalle, Valsamoggia (BO-Italy), is an example in which the passage of wild boars from the woods is used to turn over the compost pile. Every night as they passed, they go to roar, turning the decomposing material in the composter located along their path.



Zone and sectors representation (© Deep Green Permaculture, 2009. Credit is given to Angelo Eliades and Deep Green
Permaculture. Images taken from link: https://deepgreenpermaculture.com/permaculture/permaculture-design-principles/4-zones-and-sectors-efficient-energy-planning/).

Zone, elevation and sectors plan

The zoning principle can be applied to any context and not just to a farm land. As an example, the case of a social zoning is shown below, useful for assessing what type of activity to invest for the sustenance of a family who lives in an educational center.



Zone and sector representation in social context.

All needs can be met in relation to others, so I make a social zoning and by crossing with the sectors I visualize which groups of people can meet my needs.

SOCIAL ZONING based on:
closeness of relationships, physical closeness, degree of sharing ethics

- Zone 0: Family
- Zone 1: Relatives
- Zona 2: Neighborhood
- Zona 3: Local community, regional permaculture network, regional business contact and similar association, regional contacts and users
- Zona 4: national business contact, permaculture network, business contacts, users, Wwoof and the like.
- Zona 5: Wwoof and the like, international users and contacts

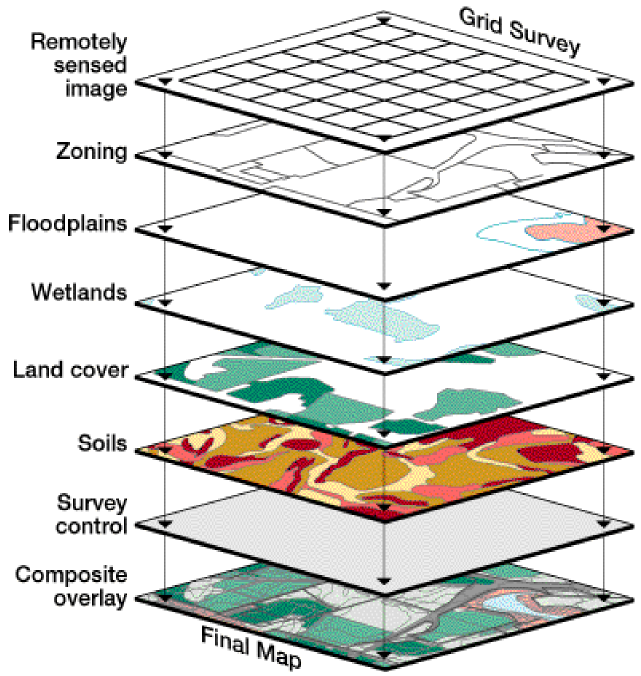
SECTORS/NEEDS
Structures: keep the home and outdoor spaces in good condition, complete the internal and external works
Sustenance: food, medicine, clothes, heat, water, electricity, gas, cars or the possibility of getting around, other small things that concern good living.
Culture-relationships: opportunity to participate in courses, meetings, exchange experiences, make visits to other projects, build (with) the community
Money: for all that I cannot get in other way
Surplus: reserve of goods, time, quality, experience, know-how, that I can share with others

Zone, elevation and sectors plan

Tools for analysis – Data overlays

In order to carry out the analyses in a site, one must possess the necessary knowledge and be familiar with the respective site in order to achieve n organization appropriate to the geographical conditions, but also to meet the needs and necessities of the project.

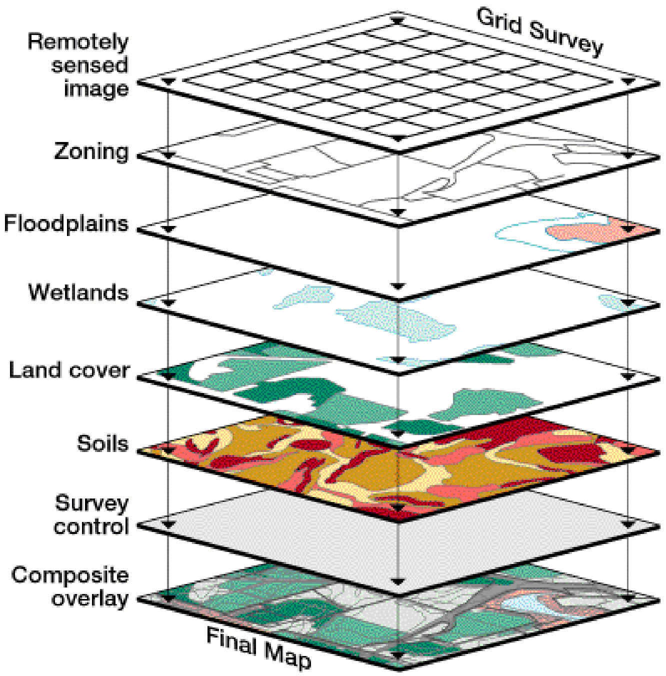
The analyses performed in graphic format are not just a simple inventory of the elements encountered in the field. They provide information about physical, biological, socio-cultural factors. The structured information will indicate the next steps to follow for the realization of the project by overlaying and connecting the field data in a synthesis of the analyses. We could call it *diagnosis*, with the role of guiding and orienting the content of the future project.



Tools for analysis – Data overlays

By overlapping all the important elements that emerge from the analyses we will be able to have a coherent general framework that will help us identify the areas of intervention, the elements that require immediate intervention, the dysfunctions encountered, but also the valuable points that deserve to be known.

Thus, the synthesis of the analyses represents a conclusion of the analyses carried out in the field with the help of the bibliography (documentation) that helps us to develop a viable project proposal, in accordance with the principles of an ecological and organic garden.



3. *Functional Analysis*

Functions are analysed by decomposing higher level functions identified through requirements analysis into lower-level functions. The requirements associated with the higher level are allocated to lower functions.

The result is a description of the product or item in terms of what it does logically and in terms of the performance required.

This description is often called the functional architecture of the product or item. Functional analysis and allocation allow for a better understanding of what the system has to do, in what ways it can do it, and to some extent, the priorities and conflicts associated with lower-level functions. It provides information essential to optimizing physical solutions.

Functional decomposition has been used from the age of time to understand the natural law and has been developed widely in the last decades in engineering and software development.

It has further evolved and has become a process for defining and understanding functionality and functional requirements of systems in the field of systems engineering.

Once this approach has been used widely some questions and doubts will naturally rise:

1. Why does it appear that some people are inherently better at performing functional decomposition than others? What factors contribute to incomplete functional decompositions?
2. What is the range of appropriateness of Functional Decomposition, as a system engineering tool?
3. Is it a difference in thinking, in manner of approach, or even in education?
4. Are there other ways/approaches to performing the decomposition?
5. What are the limits of these different ways/approaches to functional decomposition?
6. Is one way/approach to determining requirements better than another?

In general, decomposition is a notion founded in reductionism. Reductionism is an approach used to understand complex systems simply by reduction (a simplification or condensation).

The practice of analysing and describing a complex phenomenon in terms of its simple or fundamental constituents, especially when this is said to provide a sufficient explanation.

Reductionist thinking forms the basis for most modern science and axiomatic mathematics. The development of systems thinking promotes a holistic view rather than a reductionist's method. However, functional decomposition combines reductionism with systems thinking.

The methods of the reductionist may lead to incomplete decompositions because these methods do not convey or acknowledge the relationships between the reduced system components.

When patterns and phenomena are forced into confined structuredness, reduction can always help break whatever it is into its known parts (or its yet to be named parts). But ultimately, the biggest shortcoming of **reductionism** is in its inability to expand our understanding or interpret anything that is unstructured.

Systems engineering improves on this situation by viewing functions and their interfaces as the building blocks for the system. Parsing functions with their associated performances, quality, physical, informational and other views further improve the ability of systems engineering to better characterize the desired system (Langford, 2008).

The general notion of functional decomposition is to break apart (i.e., partition and objectify) the components of an object into it sub elements (Langford, 2006). The purpose of decomposition is to give precise meaning to the relationships between a whole and its parts. Decomposition specifies the structuring and distribution of these parts in terms of the transfer of information (i.e., energy) between the parts – specifically the elements of the parts). Systems engineers can and do use decomposition to obtain clarity in the understanding of the system design.

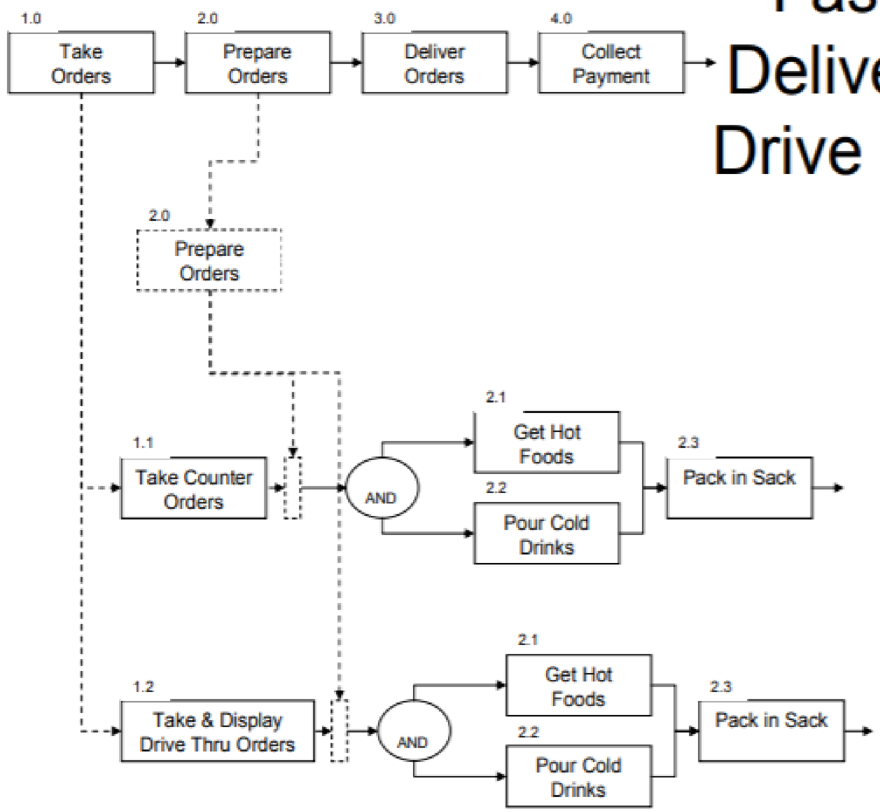
Functional decomposition is a fundamental tool of systems engineering. It maps functions to physical components (thereby ensuring that each function has an "owner") (Langford, 2008). It maps functions to system requirements. By its intention, it ensures all necessary tasks are listed and no unnecessary tasks are requested.

The typical functional decomposition results in a functional hierarchy diagram, a top to bottom parsing of general functions into their constituent parts. Higher levels of detail are found at the bottom. All functions and sub-functions are numerically designated to indicate kinship, (see Figure below) (Langford, 2006). This depiction is an example of an event-structured functional decomposition. At the top of the hierarchy are the key function(s) that define the properties of the system required to complete the system objectives (Langford, 2007). The bottom of the hierarchy covers only limited objectives - a small set of the overall list of objectives. In that fashion, the top-level function specifies the user need and the lower-level functions specify specific system's needs (Langford, 2007).

Fast Food Delivery With Drive Through Phase 1

There are many types of decomposition with different bases (e.g., functional, physical, informational).
In general, the actions of separating distinct functionality into defined components that have well-defined interfaces are one of the essential ingredients of functional decomposition.
The methodology follows a process with several steps in closed loop:

- Analysis Inputs, Use case and purpose
- Requirement Specification
- Functional and system Analysis
- Design
- verification

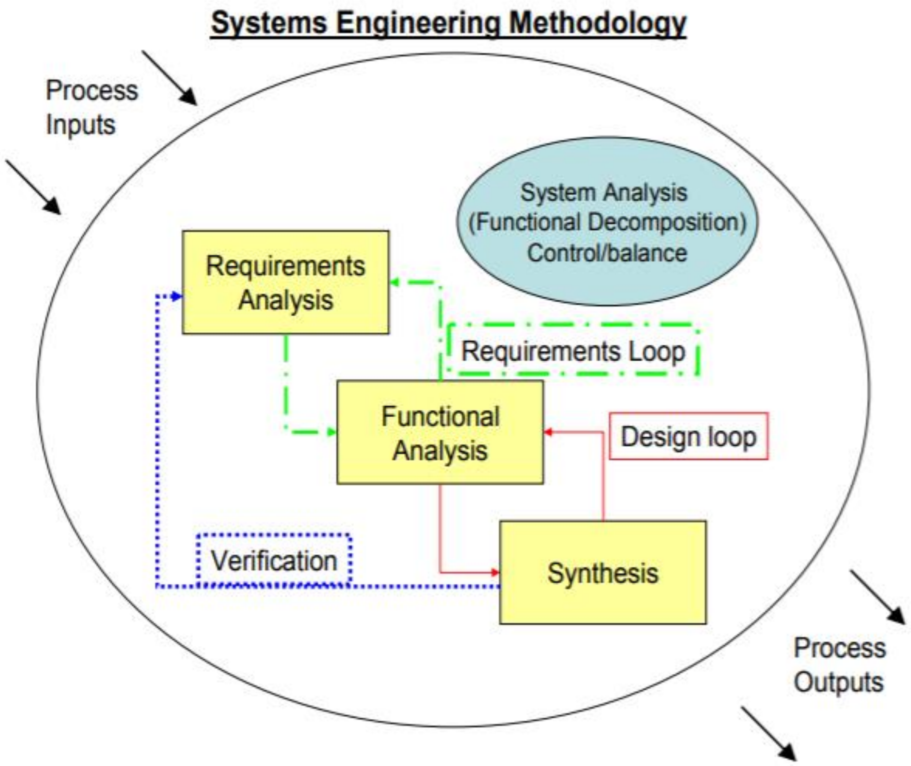


Fundamentally, there are two types of decomposition: part/whole, and generalization/specialization.
Typically, the reduction is achieved with two different approach:

- top-down approach to functional decomposition broke the main function into sub-functions, a hierarchical approach to better understanding of system complexity.
- bottom-up starting from defined parts, building through intermediate levels, until all output functions are realized.

Functional decomposition is the widely practiced methodology that deals with system complexity, focusing on intelligently partitioning the system into smaller, more definable pieces.
A large number of interacting elements or subsystems can be difficult to understand.
Managing complexity is accomplished by defining tasks whose outcomes flow together, creating a successful system that includes all the various interactions and relationships. In these cases, functional decomposition is used to decompose the different elements or tasks of the system into more manageable parts, thereby allowing the overall system behaviour to be understood as a straightforward composite of the behaviour of its many elements (Langford, 2007).
Functional decomposition is a convenient means to divide the problem into meaningful, yet understandable parts. Systems or elements can be decomposed as well in parts. Systems and functions are strictly related. Two design principle can be referenced here.

- Each element performs many functions
- Each important function is supported by many elements



Definition of System

A system is defined as an assemblage or combination of elements or parts forming a complex or unitary whole, such as a transportation system (Blanchard & Fabrycky, 1998).

A **system** is a group of interacting or interrelated entities that form a unified whole.

A **system** is described by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning.

Systems are the subjects of study of **systems** theory.

Systems consist of many interfaces, e.g., physical and functional (Langford, 2006). The physical interface comprises the things we encounter every day, such as cell phones, automobiles, shoes, etc. The functional interfaces are sometimes less obvious, but equally important as the physical interface.

The process of thinking, reasoning, and structuring facts and relationships to provide clear and unambiguous direction, is a strategy based on iterative, top-down, and hierarchical decomposition of system functions to derive requirements.

Definition of Function

The Term Function, Explained Keeping in mind the applicability of functional decomposition to the systems engineer, the term function is defined loosely as a property of the system that is required to achieve a system objective (Langford, 2007).

A function requires at least one input and at least one output to ultimately enact or realize the desires of the user. The result(s) of a function is its output(s). Decomposing functions exposes the required interfaces and connections as well as the boundaries of the beginning and ending of the domain of the function. During the decomposition process, if it is found that a function has no input or output, an incomplete decomposition has occurred.

Key Factors related to complete functional decompositions

The processes of functional decomposition, along with emphasis on key aspects that lead to insufficient decompositions, need to be explored. When done properly, the process of functional decomposition defines the 'logic' of the system.

The struggle to perform functional decomposition (from the perspectives of the unskilled or unknowledgeable) centres on two questions: (1) how does one determine if enough information has been collected about the functions? and (2) when enough is enough during the decomposition process, i.e., how far does one go with decomposition?

A usual criterion for completion of functional decomposition is to continue the process until the functional requirement is clear, realizable, and allocatable in hardware, software, and/or manual operations (Langford, 2007). The objective of generally decomposing the system into its hierarchical components helps the analyst better appreciate and deal with over stated and under stated functionality

Coupling and cohesion of system function is a means of performing an interrogation of "completeness" of the decomposition process, i.e., how far to go with decomposition. "Completeness" is defined as a reasonable level of verification that what has been conducted thus far for decomposition has sufficiently identified all necessary parts, elements, or steps to effectively and properly define the system. Total "completeness" is not a goal, rather completeness of functional decompositions means no better decomposition is likely given the knowledge and skills.

1. *Model-based design*

The specification of system based on their decomposition in elements with specific input, output and functions leads to a complete description of its model.

The same model applies to similar systems. The Logical schema underneath is the functional model that allow to achieve to same scope for different instance of same model.

There are many different mammals with different characteristics and appearance though they have the same functional schema and purpose.

The element is the object of the analysis. The result of the analysis can be used with an object-oriented approach to develop several projects with same needs and same object interactions.

Object-oriented analysis works with object-modelling techniques to analyse the functional requirements for a system. Object-oriented design elaborates the analysis models to produce implementation specifications. An object-oriented system is composed of Objects or Elements. The behaviour of the system results from the collaboration of those objects. Collaboration between objects involves those sending messages to each other. Sending a message differs from calling a function in that when a target object receives a message, it itself decides what function to carry out to service that message.

Permaculture analysis is an Object-oriented analysis (OOA) that looks at the problem domain, with the aim of producing a conceptual model (Functional layout) of the information that exists in the area being analysed. Analysis models do not consider any implementation constraints that might exist, such as concurrency, distribution, persistence, or how the system is to be built. Implementation constraints are dealt during the definition of the Physical model. The result of object-oriented analysis is a description of what the system is functionally required to do, in the form of a conceptual model. That will typically be presented as a set of use cases, one or more UML class diagrams, and a number of interaction diagrams.

Permaculture transforms the conceptual model produced in object-oriented analysis to take account of the constraints imposed by the chosen architecture and any non-functional – technological or environmental – constraints, such as transaction throughput, response time, run-time platform, development environment, or programming language.

The result is a model of the solution with a detailed architecture, a detailed description of *how* the system is to be built.

Systems science provides a means of understanding complex processes based on principles. Any system can be described by different point of view, mainly static or dynamic, functional or logical.

The perspective is described in Architecture, Schema and process. The Architecture details the functions and relation between the components of the system.

"The purpose of a functional and self-regulating design is to place elements in such a way that each serves the needs, and accepts the products, of other elements."

In *The Web of Life*, Frito Capra (1996) synthesized the systems theory by setting out three criteria for a living system — **the pattern of organization, the structure and the life process:**

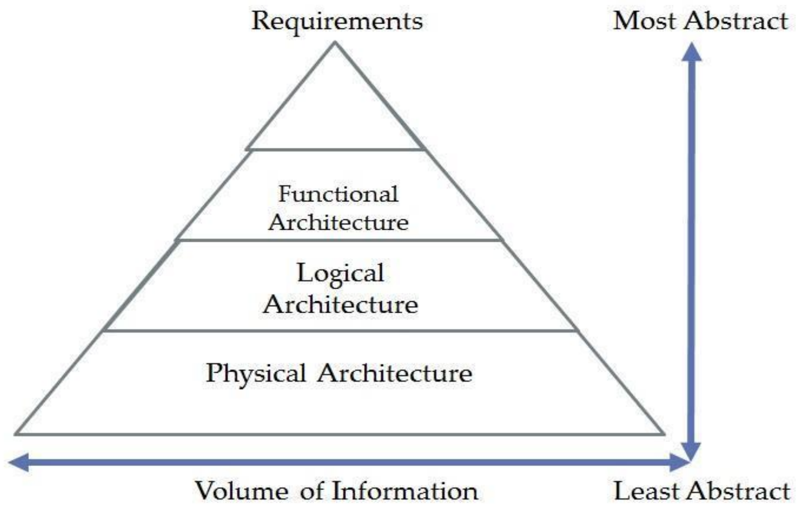
Any system can be designed taking in account different layer of representation

- **Definition of Schema: Functional**
- **Definition of Schema: Logical**
- **Definition of Skeleton: Physical Schema**
- **Definition of Process**

Functional architecture defines a solution-independent representation of the design; composed of pure functions. Functional architecture is defined as the system functions contained in black-box specifications (as operations) across the submarine system hierarchy.

Logical architecture represents an intermediate abstraction between functional and physical architecture. Components of a logical architecture represent abstractions of physical solutions. These units have many different physical characteristics but they share many common properties, such as power output and weight and they perform a common set of functions a component of a logical system thus defines functions, properties and interfaces that are common to a range of physical design alternatives. Most importantly, logical architecture remains largely independent of technology or suppliers and provides a reasonably stable baseline from which physical architecture can be derived and evolve. Logical systems and components are implemented in SysML as blocks with a «logical» stereotype applied3.

Physical architecture is composed of tangible items of equipment that have been selected for a specific submarine subsystem design. If the information is available, physical components can be characterised by their supplier datasheets. Physical architecture also takes into consideration constraints such as redundancy as well as the arrangement and spatial layout of a particular submarine concept. Physical systems and components are implemented in SysML as blocks with a «physical» stereotype applied.



Levels of System Architecture and Abstraction

"… [An] organization denotes those relations that must exist among components of a system for it to be a member of a specific class. Structure denotes the components and relations that actually constitute a particular unity [or thing] …"

Any living being is made of different elements interconnected by a net of relations. A relation can be the representation of a material exchange as well of information or interdependency of services or functions.

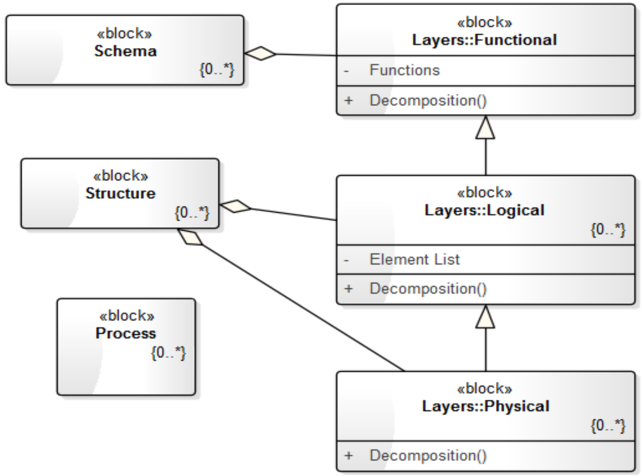
A system can be described by:

- **Skeleton** – A static picture of the elements as they are in the concrete world with specific description and features
- **Schema** – a static Logical picture of the elements and their functional net.
- **Process** - the description of the dynamic activities running on

The effective advantage of this approach is that the functional architecture can be used for the development of several systems, with different specification of the logical and physical architecture.

This is the most impressive enhancement provided by the permaculture approach. Look at the nature, try to understand, and copy paste or integrate the efficient and working system in your design.

Let's try to do the conception of some common object taking in account the 3 proposed perspectives.
Everyone knows to ride a Bike. Which is the functional and logical and physical architecture of a Bike?
Functional architecture: The rider provides power that moves the wheels. The rider shall be able to steer
Logical Architecture: The structure of a bike shall connect the wheels. The seat shall support the rider. The rider shall push the pedal.
Physical architecture: The structure of a Bike Model 101010 is made of Iron. It is blue and its weight is about 8Kgs.
The block diagram of this schematic perspective is proposed here:

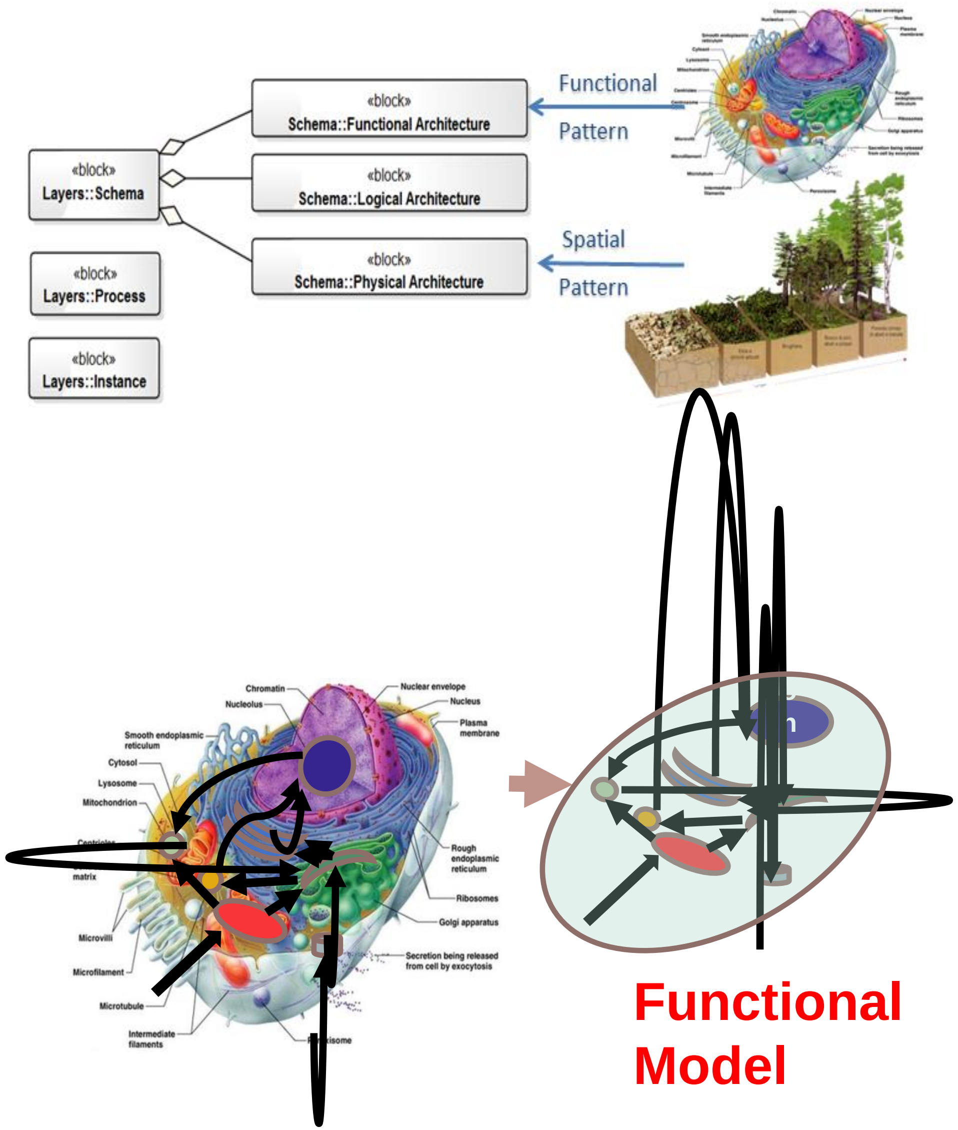


Take a look at the functional pattern of a Cell. The human being is made of cells, as system of systems. It is possible to observe how the cell functional schema works. From the understanding of the cell schema, it is possible to define Object oriented architecture with the following main elements:

- a nucleon to process data
- a membrane to separate the in from the out
- A Golgi apparatus to digest and produce energy.
- And so on…

The cell functional model can be used to represent the human being functional schema as well. The same model can be used as reference schema for a farm, or a business.

The nature is an ever-ending source of working and effective pattern and model to be inspired from.

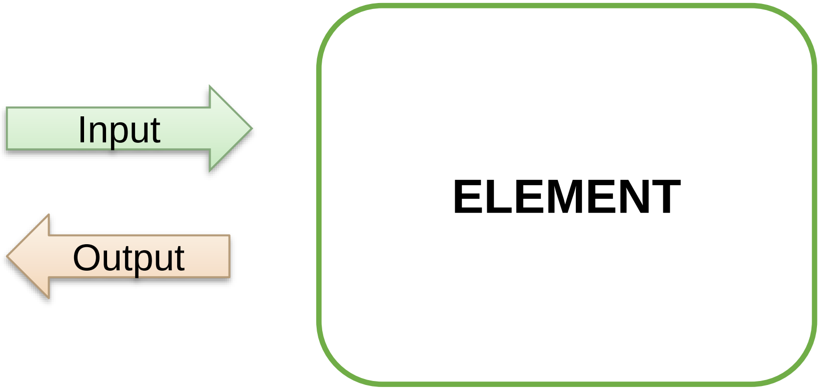


Functional analysis – Elements analysis

The one described here is the most important brick to be used for the overall design architecture, the analysis of the elements.
It is an analytical design tool that takes its cue from the web of life, the reality of the interdependence of all things.
If the goal of PC design is to create resilient, autonomous and low energy consumption systems, this is the main method to achieve it.
The method helps us find useful connections between the different elements of a system, ensuring that the various energy and resource needs of the various components are satisfied, as far as possible, in a harmonious framework.
The more useful connections will be present within a system, the less work it will require for maintenance by the operator.

The method starts from the exploration of the elements of a system, both those present and those that would like to be inserted.

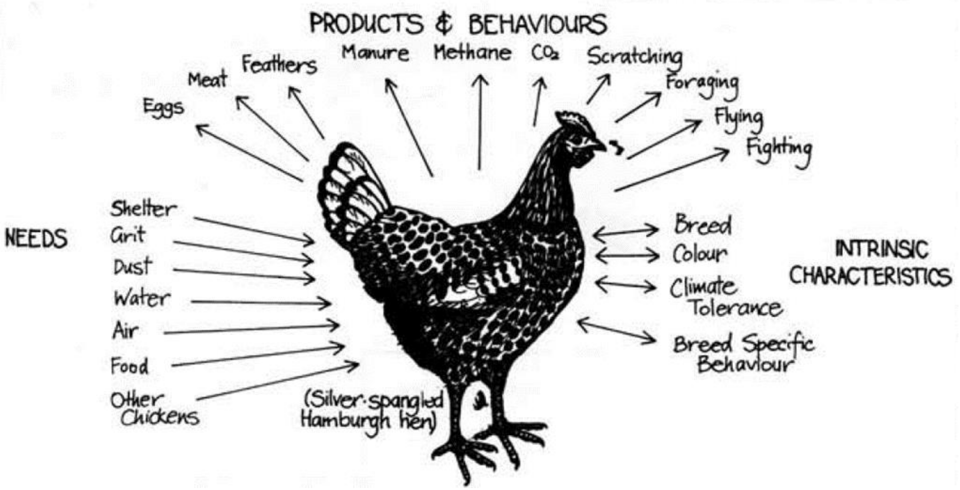
For simplicity, we can think of two successive stages of this analytical process.



Functional analysis – Elements analysis

Step 1
The first step to do is a list of characteristics, needs and products of each element (already present or you want to insert).
The classic element brought for example for this type of analysis, probably because of its versatility, is the hen, described in the image.

The **needs** of the hen, as illustrated in the image, are all it needs to live well, therefore from basic needs such as food and water, to an optimal social and physical environment, or at least tolerable, to guarantee the animal healthy living with as little stress as possible.
The **products** and behaviours are what in this case the hen releases into the environment, primary products such as eggs, feathers, manure, and products that derive from them.
For example, you can prepare many dishes with eggs, with feathers and pens you can make dusters, insulators or special fertilizers, with manure you can prepare various types of compost.
It can be said that the list of derivative products is limited only by the lack of information and the specific needs of the manager.
The typical behaviour of the hen is to scratch and go in search of insects and seeds to feed, things that make it useful in certain situations where we want to carry out a control of weeds and pests.
The **intrinsic characteristics** are related to the breed, therefore the ability to adapt / tolerance to environmental conditions (hot or cold), the predisposition to behave in a certain way, the size, the colour, etc... For example, breeds suited to production of eggs, breeds more prone to hatching, with the ability to fly on trees to defend themselves from predators, or vice versa heavy species that can be contained by low fences, depending on the greater usefulness that this characteristic can have in relation to the system.



Products and behaviour of a hen. Analysys of these inputs and outputs are critical to self-governing design. A deficit in inputs creates work, whereas a deficit in output use creates pollution.

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On the first two aspects it is considered important to make some considerations that lead us directly to the next step:
The products of an element are also its **output**, what it brings to the rest of the system; they are **resources** if they are used productively, but they can become **polluting** if misused or not used constructively elsewhere in the system.
For example, chicken manure is certainly a resource for producing good compost, but also a source of bad smells and an unhealthy environment if not handled properly.
The needs of the element are required, **inputs** that must be provided by the manager or some other element of the system. The need to guarantee these inputs can turn into **extra work**, if it is not automatically provided by another element or if it is disproportionate to the manager's real capabilities / possibilities.

Functional analysis – Elements analysis

Output Products - Functions

Product
- Egg
- Pollina (feces and urine)
- Chicks
- Meat
- Feathers
- Ch4
- Heat
- CO2

Function
- Soil Tillage
- Pest control - pest control
- He eats
- Defence
- Combat
- Hatching
- It makes sounds

Input Needs

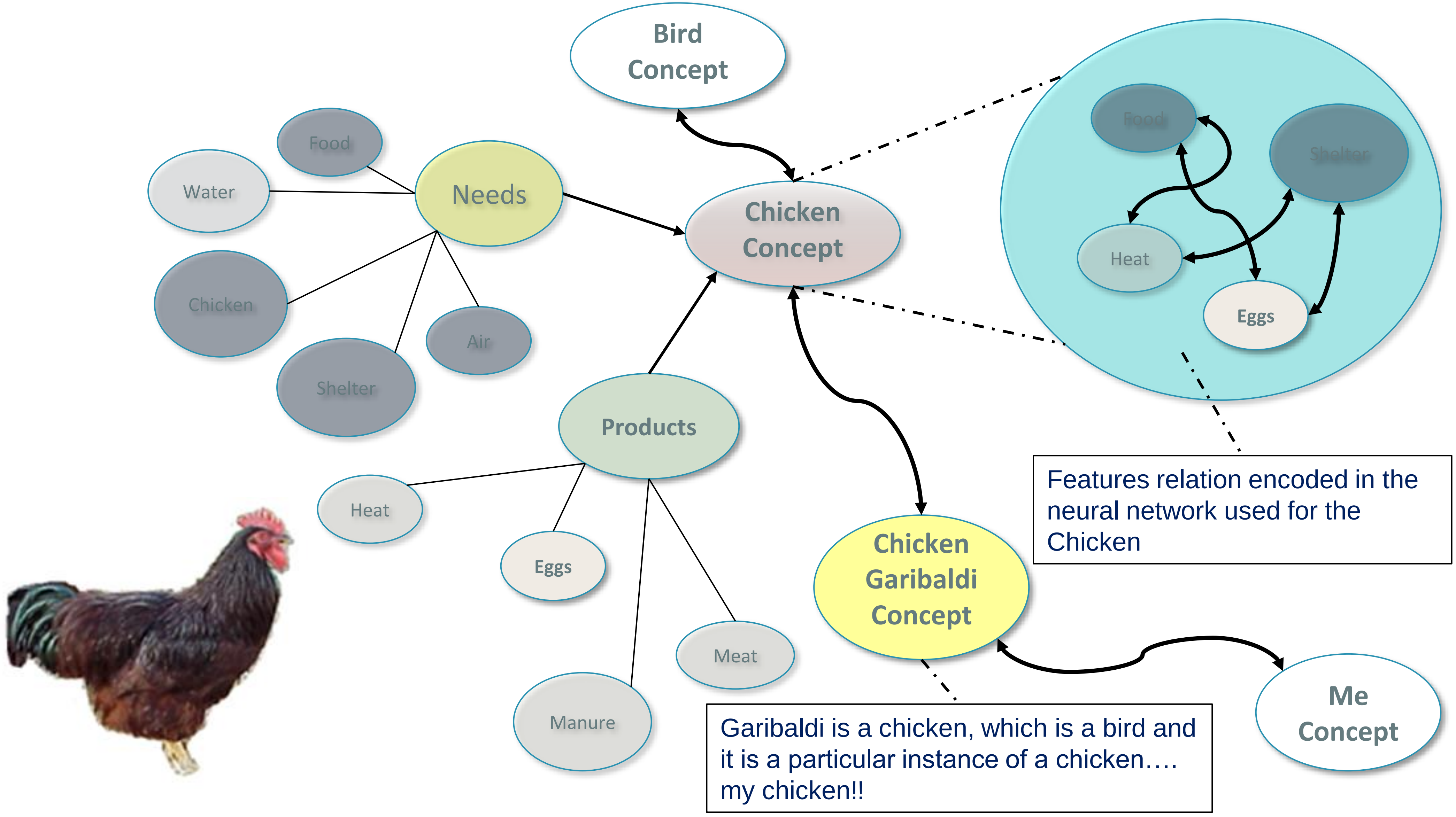
Products
Food (cereals, vegetable waste, earthworms, insects etc)
water
Air

Company (Gallo and others like it)
Protection
Space Sqm (shelter, hatching, scratching, hygiene
Light
To sleep
Scratch

Nature (aggressive or docile)
Fly or not
Noisy or not
Dirty or clean
Productive or not
Hatching or not
Of sound and robust constitution or not
Color
Reproductive capacity or not

characteristics

Functional analysis – Elements analysis



The Chicken System

Functional analysis – Elements analysis

Step 2

The next step is therefore to find connections between the elements, so that the needs of one are satisfied by the products of another.
Taking the example of the hen, we can ask ourselves: "Are there any elements of the system that could provide food for these animals?” in the view of a "lazy manager" of the system "Is there a way to make hens can independently take this food without the need for me to bring it to them every day?".
If the first question leads us to find out which elements may have a relationship with the hen, the second offers us a hint as to how they can be arranged in space.

The relative positioning of the elements, already seen in our paragraph on the principles of design, therefore comes into play, which translates into an optimal spatial arrangement of the elements in favour of useful interactions and a reduction in energy contributions by the operator.
For this purpose, the use of a map to view the elements and routes can be very useful.
The following images show an example of a typical family-run company in which the same elements, if instead of being isolated are functionally arranged and connected to each other, make the system much more efficient.

The following images show the plan for a farm in both case of integrated and non-integrated system.

Functional analysis – Elements analysis

Plan of a non-integrated system.

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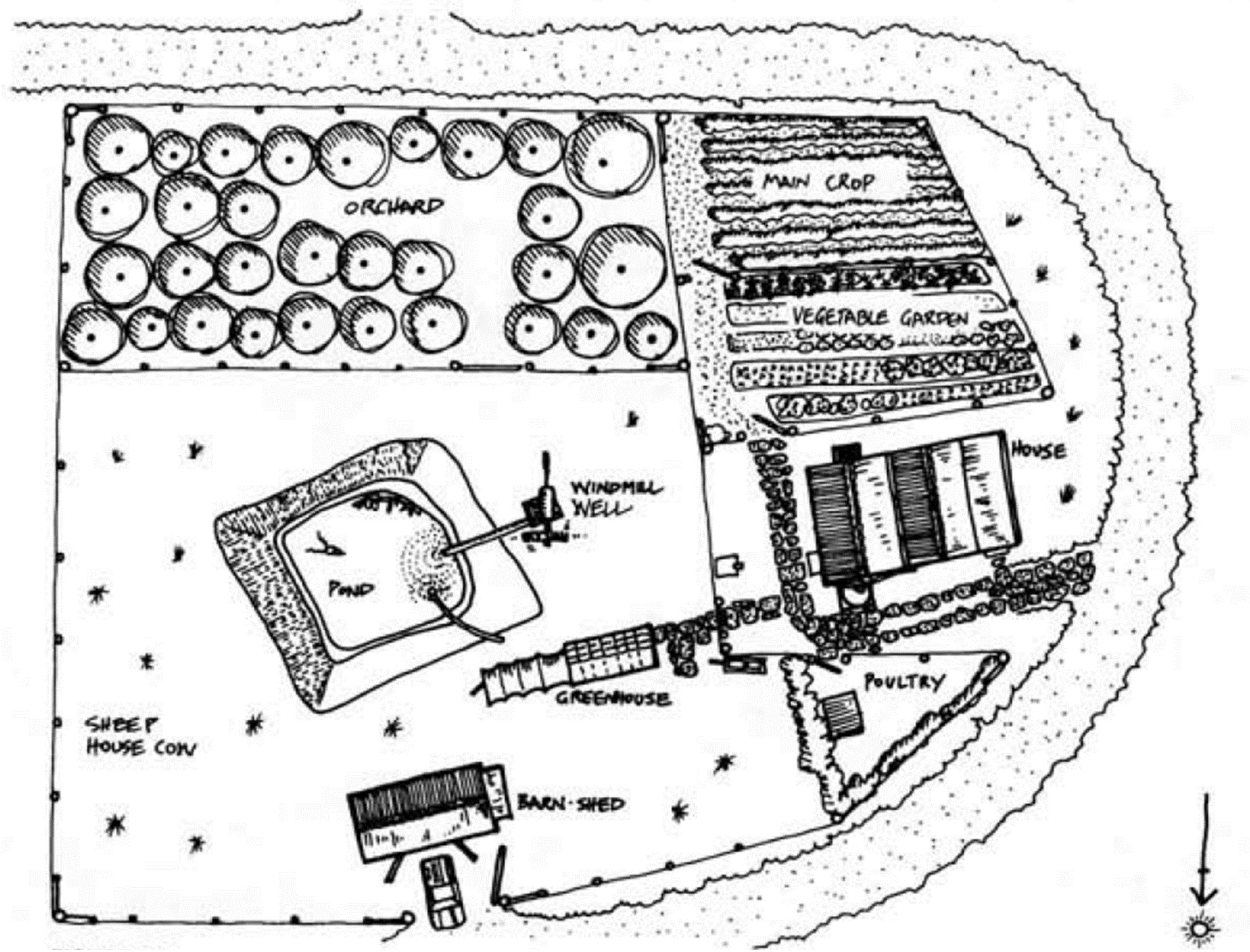

Functional analysis – Elements analysis

Plan of a the integrated system of the previous image.

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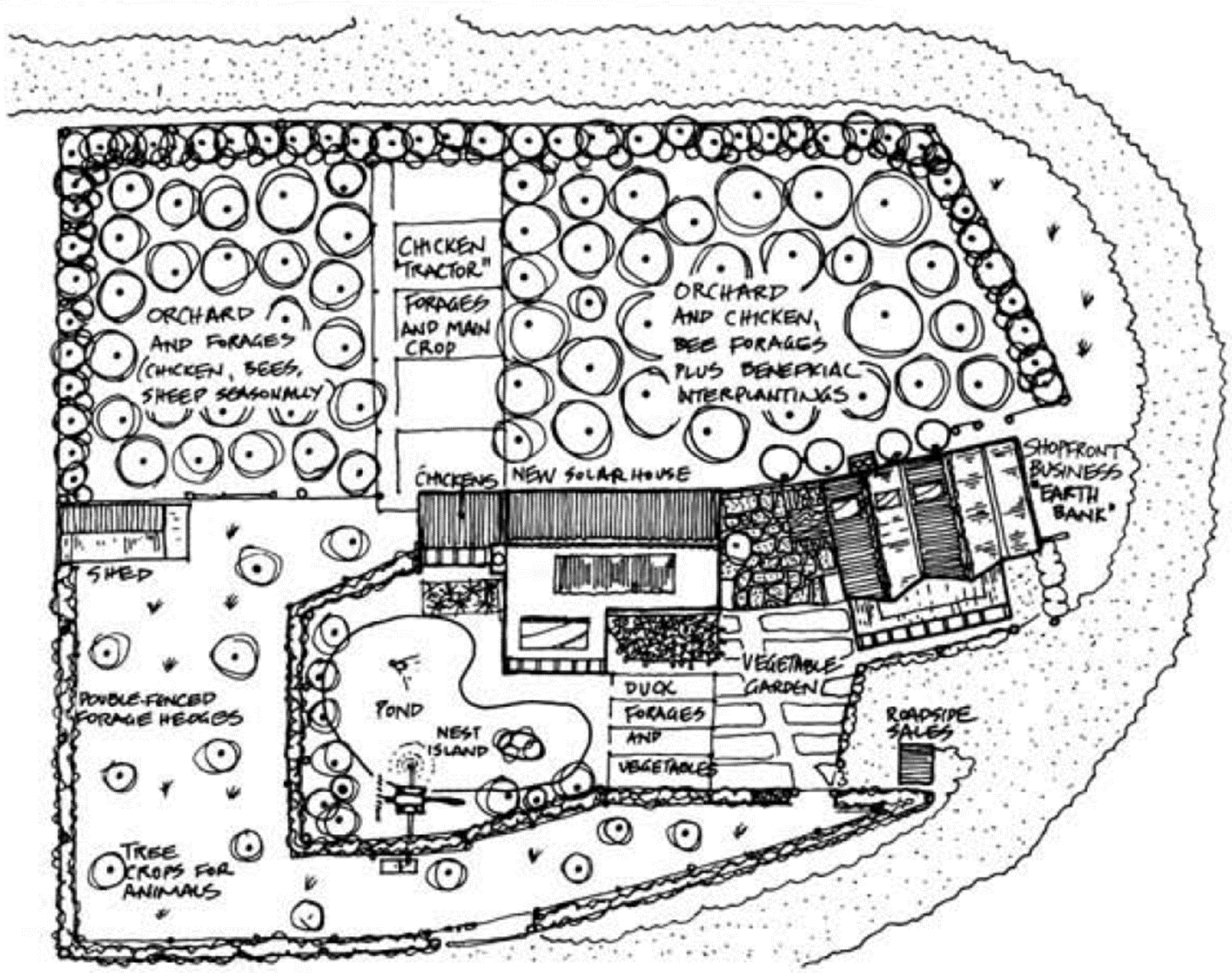


Functional analysis – Elements analysis

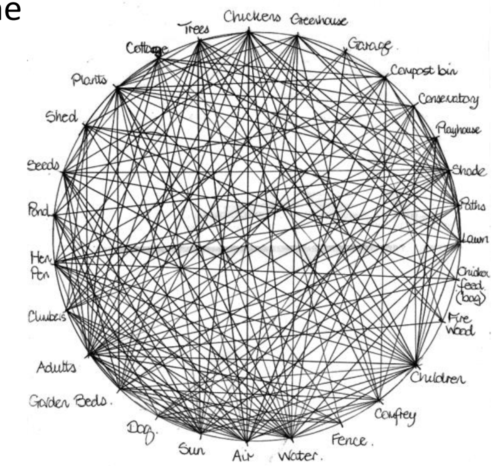
Based on the characteristics of the place and the operator, the analysis can suggest which elements to insert, maintain or delete from the system, where to position them and, for the same element, which type / species to target.

This analytical work should be done for each element, including the people who live in the system, in order to design an adequate and proportionate system for those who are responsible for management and to provide the necessary energy inputs.

The analysis of the elements helps us to create useful relationships between the different components of the system, which is exactly what happens in nature: the cycles are closed and the energy circulates in the systems fluidly producing an abundance of resources. A human system designed with a careful choice of well-positioned elements can work like a natural system requiring a minimum of energy for maintenance.

It is considered appropriate to underline how, although this tool can theoretically be used by the designer on the basis of a map or other IT tools, its application cannot be separated from a good observation of the place which is irreplaceable.

There is also a factor of variability and unpredictability to be taken into account when the design is passed on to implementation: having to do with living systems, there is no total possibility of control. We design a system as we would like it to be, with the awareness that the elements will interact with each other according to how they will have the opportunity to express themselves and the role they will spontaneously take in this system. Only by observing how the hen behaves in the orchard or the donkey in the grove, will we be able to understand how to re-modulate the design towards the ideal situation.



Architecture Specification

The Architecture details the functions and relation between the components of the system. The Architecture of the project provides the full understanding of the system via different perspectives.

During the systems science process architectures are generated to better describe and understand the system. The word “architecture” is used in various contexts in the general field of engineering. It is used as a general description of how the subsystems join together to form the system. It can also be a detailed description of an aspect of a system: for example, the Operational, System, and Technical Architectures used in Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance, and software intensive developments. However, Systems Engineering Management recognizes three universally usable architectures that describe important aspects of the system: functional, physical, and system architectures.

- The Functional Architecture identifies and structures the allocated functional and performance requirements.
- The Physical Architecture depicts the system product by showing how it is broken down into subsystems and components.
- The System Architecture identifies all the products (including enabling products) that are necessary to support the system and, by implication, the processes necessary for development, production/construction, deployment, operations, support, disposal, training, and verification.

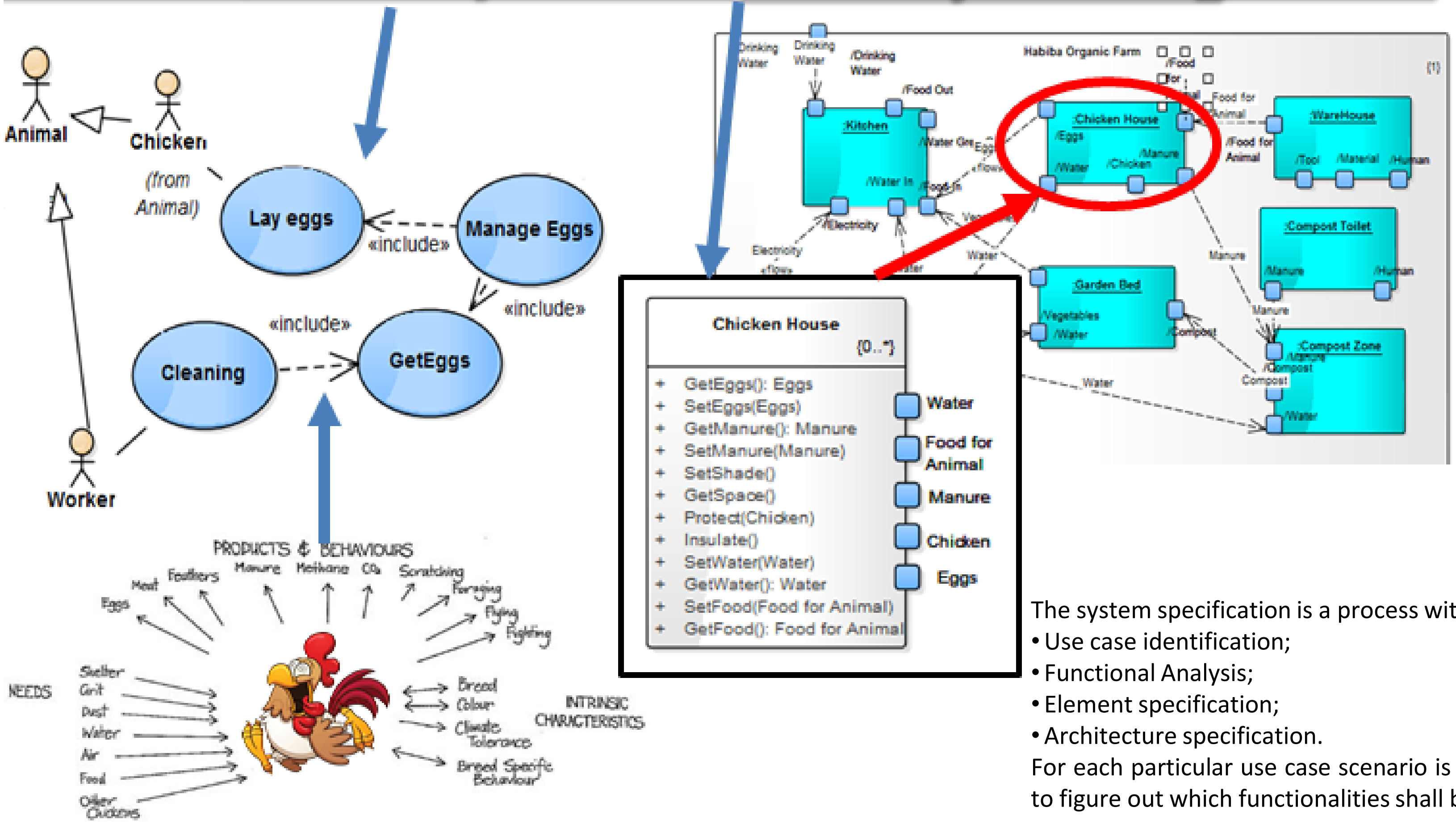
The Permaculture design is a standardized, holistic management process for development of system solutions that provides a constant approach to system development in an environment of change and uncertainty. It also provides for simultaneous product and process development, as well as a common basis for communication. Permaculture design ensures that the correct tasks get done during development through planning, tracking, and coordinating.

Permaculture design management is a multifunctional process that integrates life cycle functions, the systems engineering problem solving process, and progressive baselining.

Permaculture design process is a problem-solving process that drives the balanced development of system products and processes.

Architecture Specification

Actors → Use Cases → Functional Analysis → Elements → Architecture → Design



The system specification is a process with linear development of the steps reported here below:

- Use case identification;
- Functional Analysis;
- Element specification;
- Architecture specification.

For each particular use case scenario is possible to decompose the system in the required element and try to figure out which functionalities shall be performed by actors and element.

Functional analysis – Elements analysis

The design of a productive system is complex, as well the organization of a Farm, though for each system independently by the size, it is possible to identify specific use case that can be designed in the same way.

For instance, it is possible to imagine the use case to investigate related to the chicken house maintenance.

The development of this use case is reported in the picture above.

The actors are identified in the following:

- Chicken
- Worker
- Farmer
- Customer

The foreseen tasks are the following:

- Chicken house maintenance
- Chicken care
- Workday organization
- Eggs marketing
- Eggs sale

The possible involved elements are the following:

- Chicken house
- Worker/Woofer
- Chicken
- Farmer
- Tools for the chicken house maintenance

Products that are interchanged by the elements are:

- Eggs
- Water
- Food
- Manure
- Money
- Information

Functional analysis – Elements analysis

The functional analysis defines the required activities to be covered and starting from this it is possible to allocate specific tasks to the integrated element.

Here below are reported some Functional Requirement divided by the related element that shall be covered to ensure the system working properly:

Chicken House

- The chicken house shall provide
  - space
  - air
  - connection to the water
  - illumination
  - shade
  - Protection against predators…
- The chicken house shall allow the cleaning while the chicken is stored.
- The chicken house shall have double/single... access

Chicken

The Chicken shall be able to lay eggs

The chicken shall be able to have comparing with other chickens…

Worker

- The worker shall provide food to the chicken twice a day
- The worker shall provide water to the chicken once a day
- The worker shall check and in case get the eggs from the chicken house once a day.

The above reported example allows the readers to appreciate the reason of the proposed approach. Several design options and boundaries and resource identification can be realized and identified with the investigation of a simple case scenario.

Functional analysis – Elements analysis

To enable a design component to function, we must put it in the right place and value their connections with the system.

This is applicable for living element, e.g. ducks placed in a swamp may take care of themselves, producing eggs and meat and recycling seeds and frogs, as well for other components, where connectors might shall be arranged e.g. a solar collector linked by pipes to a hot water storage. And we should observe and regulate what we have done.

Regulation may involve confining or insulating the component or guiding it by fencing, hedging, or the use of one-way valves. Once all this is achieved, we can relax and let the system, or this part of the system, self-regulate. Having listed all the information we have on our component, we can proceed to placement and linking strategies which may be posed as questions:

- Of what use are the products of this particular component (e.g. the chicken) to theneeds of other components?
- What needs of this component are supplied by other components?
- Where is this component incompatible with other components?
- Where does this component benefit other parts of the system?

The answers will provide a plan of relative placement or assist the access or one component to the others.

We can choose our other components from some common elements of a small family farm where the family has stated their needs as a measure of self-reliance, not too much work, a lot of interest, and a product for trade (no millionaire could ask for more!).

THE HOUSE needs food, cooking fuel, heat in cold weather, hot water, lights, bedding, etc. It gives shelter and warmth for people. Even if the chicken is not allowed to enter, it can supply some of these needs (food. feathers, methane). It also consumes most food wastes coming from the house.

THE GLASSHOUSE needs carbon dioxide for plants, methane for germination, manure, heat, and water. It gives heat by day and food for people, with some wastes for chickens. The chicken can obviously supply many of these needs, and utilize most of the wastes. It can also supply night heat to the glasshouse in the form of body heat.

THE ORCHARD needs weeding, pest control, manure and some pruning. It gives food (as fruit and nuts), and provides insects for chicken forage. Thus, the orchard and the chickens seem to need each other, and to be in a beneficial and mutual exchange. They need only to be placed together.

THE WOODLOT needs management, fire control, perhaps pest control, some manure. It gives solid fuel, berries, seeds, insects, shelter, and some warmth. A beneficial interaction of chickens and woodlot is indicated.

THE CROPLAND needs ploughing, manuring, seeding, harvesting and storage or crop. It gives food for chickens and people. Chickens obviously have a part to play in this area as manure providers and cultivators (a large number of chickens on a small area will effectively clear all vegetation and turn the soil over by scratching).

THE POND needs some manure. It yields fish, water plants as food and can reflect light and absorb heat.

In such a listing, it becomes clear that many components provide the needs and accept the products or others.

However, there is a problem. On the traditional small farm the main characteristic is that nothing is connected to anything else, thus no component supplies the needs of others, in short, the average farm does not enjoy the multiple benefits of correct relative placement, or needful access of one system or component to another.

Architecture Specification – Diagram

The desire to transition Systems science from a document centred process model to a modelling approach is suggested as critical.

System science have used many different types of graphical means to modelling projects, including hand drawings on the traditional white board, but until the development of the Systems Modelling Language (SysML) there had not been a systems engineering standard modelling language, which had been recognized by the International Council on Systems Engineering (INCOSE, 2007).

A standard modelling language allows the system engineer to communicate system requirements and design specifications among other engineers. Modelling languages such as the Unified Modelling Language (UML) and Systems Modelling Language (SysML) provide such means of effective communication. For example, we know that while driving our vehicle we will come across a red eight-sided sign. This sign instructs the driver to stop their vehicle, even without the word “stop” printed on the sign. The symbol has been known for the action to stop and take caution. The tools within the language help dissect the system in order to verify requirements, functionality, behaviour, etc. which allows early identification of design issues and system effectiveness to meeting customer goals.

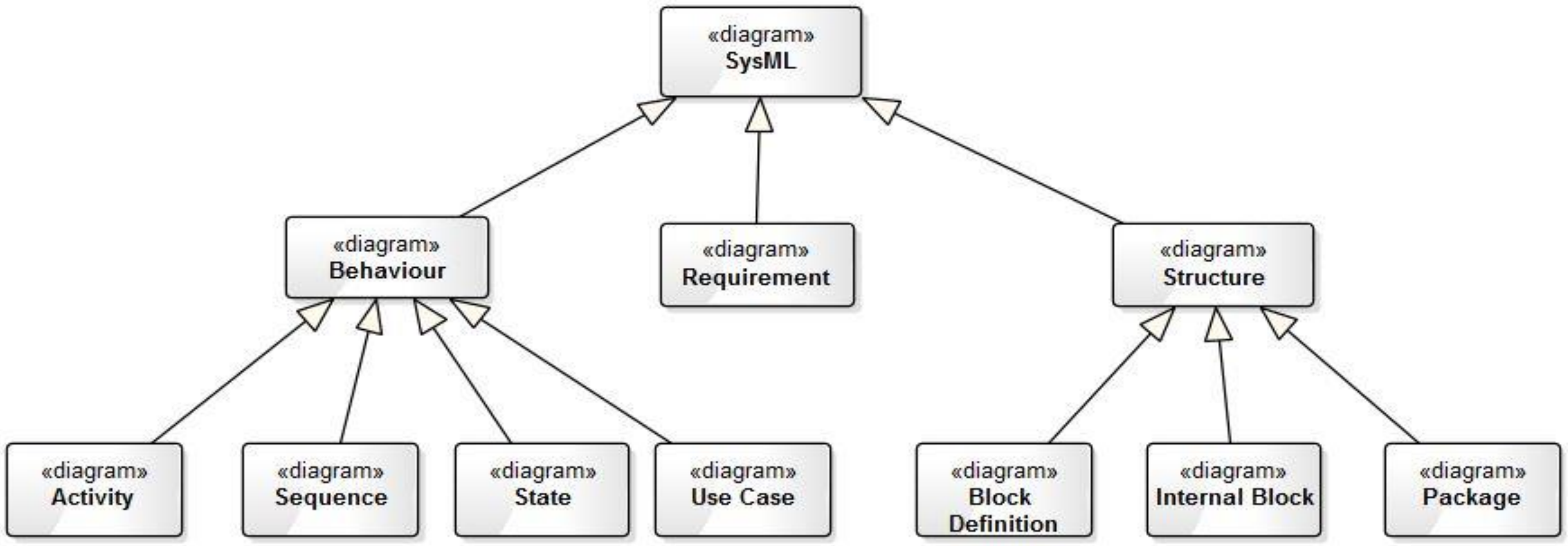
UML provides a defined method of communication that consists of specific graphical formats for systems. This graphical format seems to aid in understanding complexity and de-convolving the twists of interactions and relationships of systems. More and more this graphical method of communication is becoming increasingly important as systems become more complex.

UML is not a tool, but rather more of a format that controls how designers communicate by means of diagrams such as various types of diagrams to depict Use Cases, objects, states, activities, composite structures, interaction overviews, sequences, components.

SysML was developed to assist the systems designer with the specification, analysis, design, verification and validation of a broad range of complex systems.

Architecture Specification – Diagram

What is the **System Modelling Language** (SysML)? SysML is a general-purpose architecture modelling language for Systems applications.
SysML supports the specification, analysis, design, verification and validation of a broad range of systems and systems-of-systems. These systems may include elements, products, information, processes, personnel, and facilities.
The structural layout of SysML is shown in Figure below.



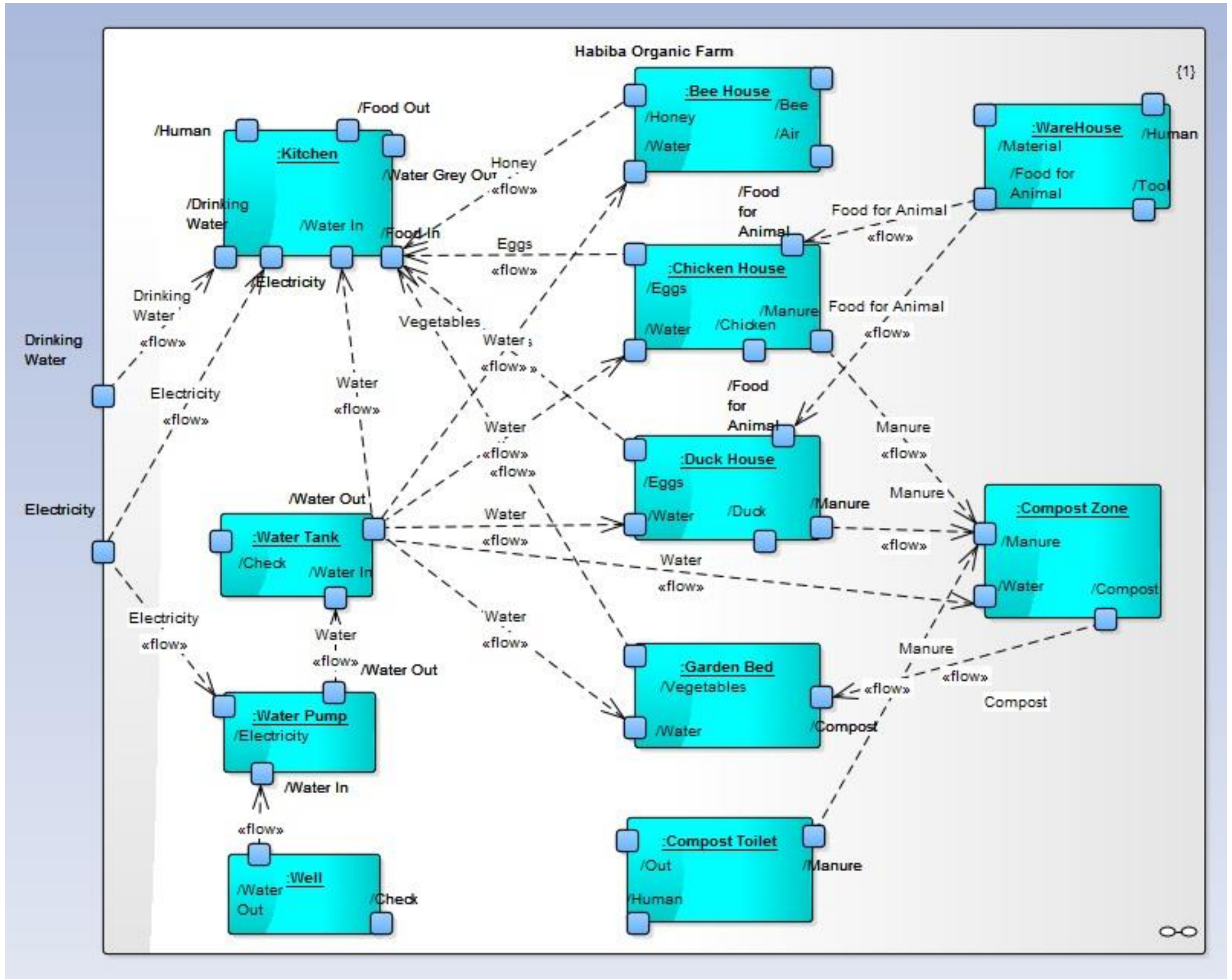
For the Permaculture design purpose the following diagrams will be taken in account:
Structure - describing the static and physical definition of a system
- Block diagram

Behaviour - describing the dynamic definition of a system
- Use Case diagram
- Activity diagram
- Sequence diagram

Architecture Specification – Diagram

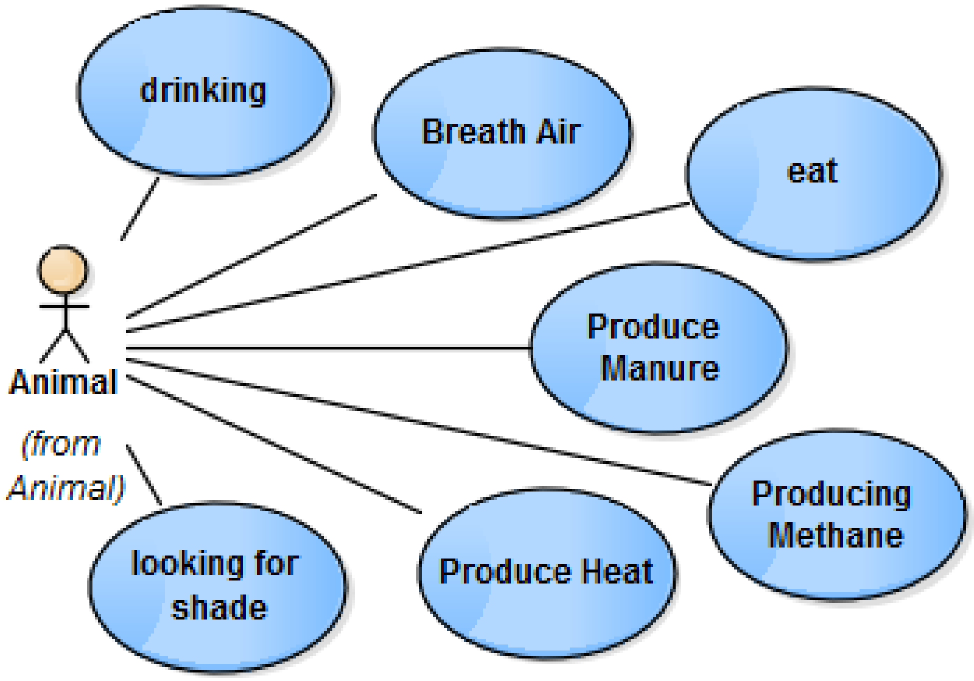
Block Definition Diagram. A «block» is a modular unit of structure in SysML that is used to define types of physical entities (e.g. system, system component part, external systems, or items that flow through the system), as well as conceptual entities or logical abstractions.

Internal Block Diagram is a block diagram that describe the internal architecture of a block with the specification of the input/output information flow connected to the ports of the block.



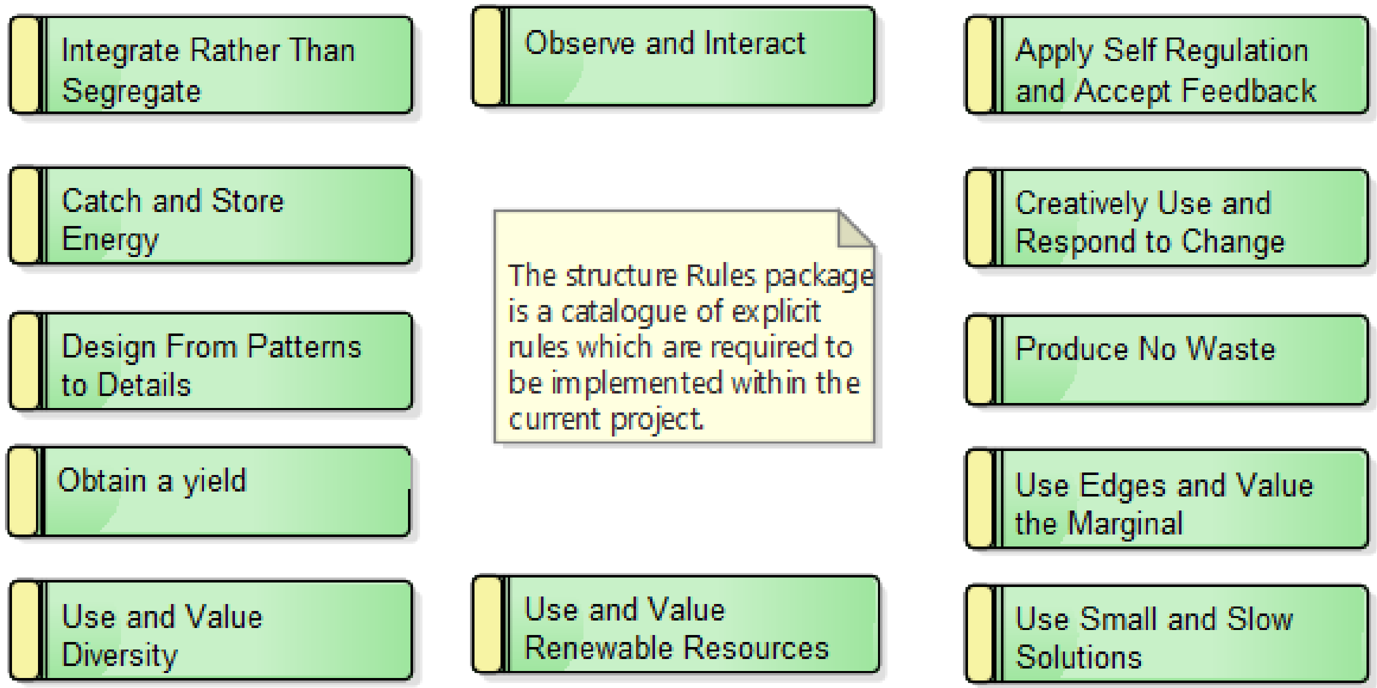
Architecture Specification – Diagram

A use case diagram at its simplest is a representation of a user's interaction with the system that shows the relationship between the user and the different use cases in which the user is involved. A use case diagram can identify the different types of users of a system and the different use cases and will often be accompanied by other types of diagrams as well. The use cases are represented by either circles or ellipses.



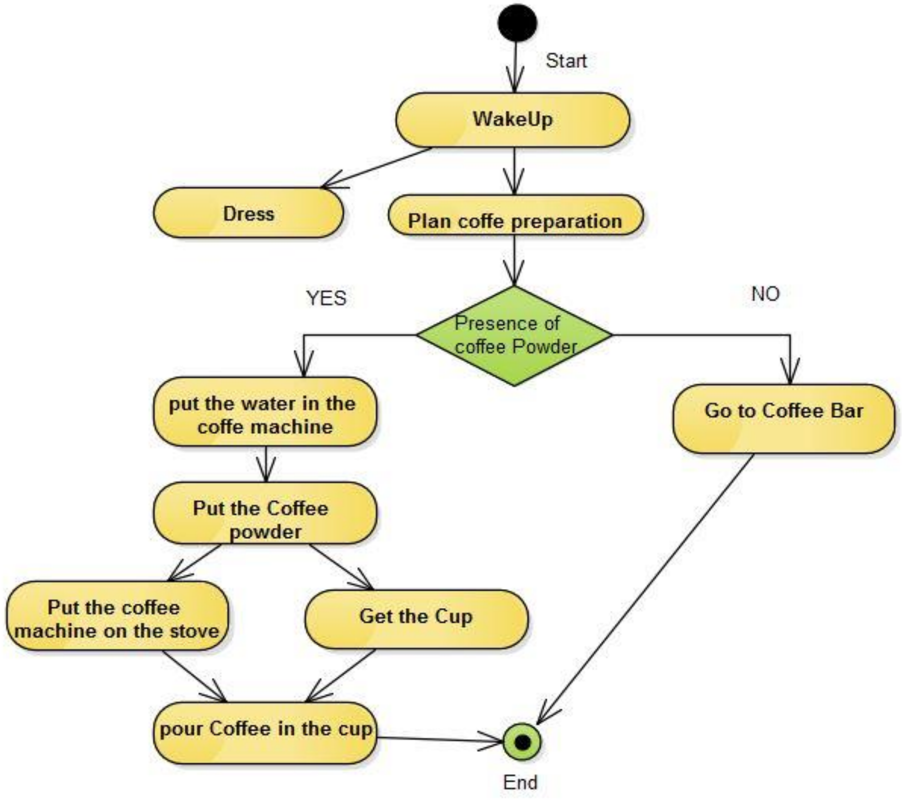
Architecture Specification – Diagram

A requirement diagram is a diagram specially used in SysML in which requirements and the relations between them and their relationship to other model elements



Architecture Specification – Diagram

Activity diagrams are graphical representations of workflows of stepwise activities and actions[1] with support for choice, iteration and concurrency. In the Unified Modeling Language, activity diagrams are intended to model both computational and organizational processes (i.e., workflows), as well as the data flows intersecting with the related activities.[2][3] Although activity diagrams primarily show the overall flow of control, they can also include elements showing the flow of data between activities through one or more data stores.



Architecture Specification – Diagram

A sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario. Sequence diagrams are typically associated with use case realizations in the Logical View of the system under development. Sequence diagrams are sometimes called event diagrams or event scenarios.

A sequence diagram shows, as parallel vertical lines (lifelines), different processes or objects that live simultaneously, and, as horizontal arrows, the messages exchanged between them, in the order in which they occur. This allows the specification of simple runtime scenarios in a graphical mannerA sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario. Sequence diagrams are typically associated with use case realizations in the Logical View of the system under development. Sequence diagrams are sometimes called event diagrams or event scenarios.

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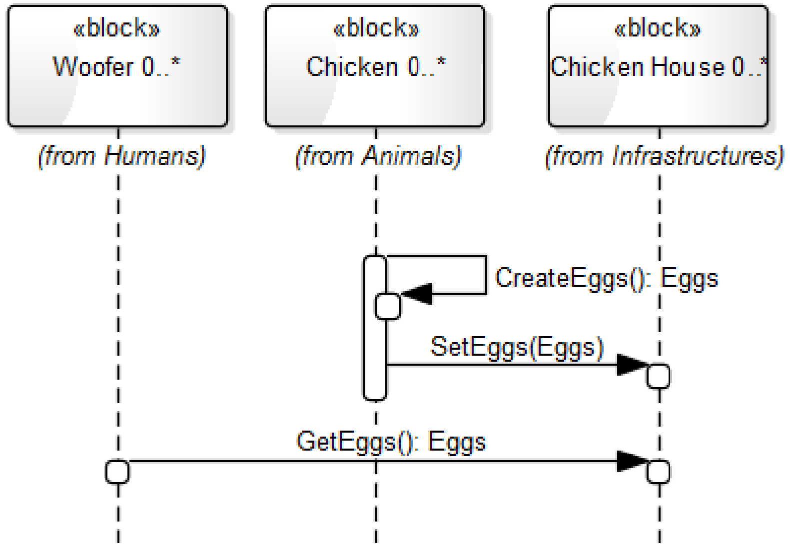


Architecture Specification – Diagram

A Test Case is used to give a practical example of Architecture specification of a system.

At the end of each subchapter, the test case is analysed and specified with the specific type of diagram.

The TestCase is built over a common daily activity: “Get the Coffee in the Morning”.

TESTCASE:BREAKFAST

This simple task is described therefore with:

- Use case
- Block diagram
- Activity diagram
- Sequence diagram

The approach to be used for a simple task or for a complex number of tasks is the same.

The specification of a system can be performed in an incremental approach with the analysis of all the parts is constituted by.

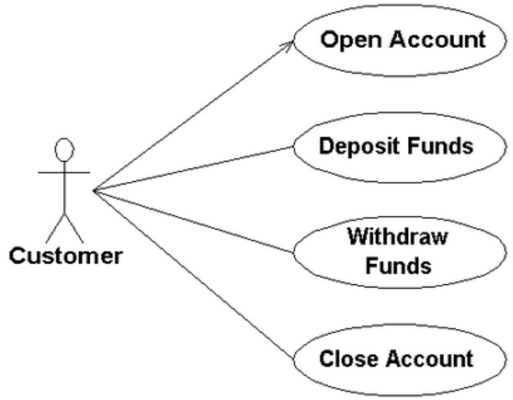
Architecture Specification – Diagram

Use Case Diagram - Behaviour
Use Case diagrams provide descriptions of system functionality, including actors. Actors are external to the system and include domains such as the environment.
The Use Cases represent usage(s) of the system, i.e., the subject, which correspond to the basic functionalities that the system and actors support (Friedenthal & Burkhart, 2007)
Functionality is represented in Use Case Diagrams in a top-down fashion. Use Case Diagrams represent behaviour as relationships, which are rather different from Functional Flow Diagrams that represent behaviour in a linear fashion, captured in a time-framed way. However, as with functional decomposition, the Use Case Diagram process begins by identifying the top-level system functionality layout of the Use Case diagram. This top level is a description of what the system is to do, but not how it will do it.
A use case diagram is "a diagram that shows the relationships among actors and use cases within a system. "Use case diagrams are often used to:

- Provide an overview of all or part of the usage for a system or organization in the form of an essential model or a business model
- Communicate the scope of a development project
- Model your analysis of your usage requirements

A use case describes a sequence of actions that provide a measurable value to an actor. A use case is drawn as a horizontal ellipse on a UML use case diagram, as you see in the figure.

1. Use Case Names Begin with a Strong Verb
2. Imply Timing Considerations by Stacking Use Cases. As you see in the figure, the use cases that typically occur first are shown above those that appear later.

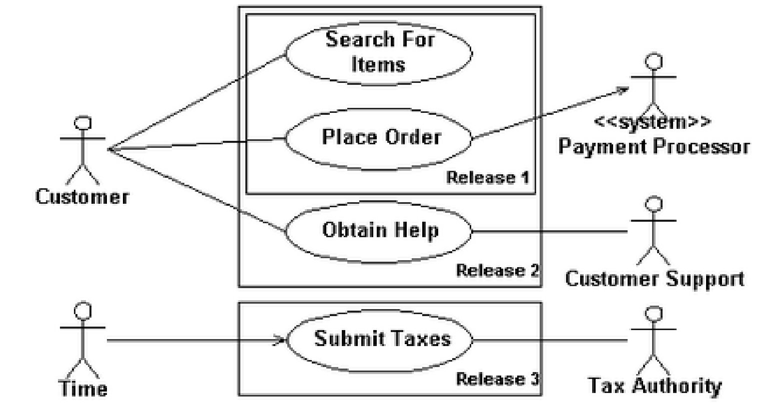


Implying timing considerations between use cases.

Architecture Specification – Diagram

<u>Actors</u>

An actor is a person, organization, or external system that plays a role in one or more interactions with your system (actors are typically drawn as stick figures on UML Use Case diagrams).



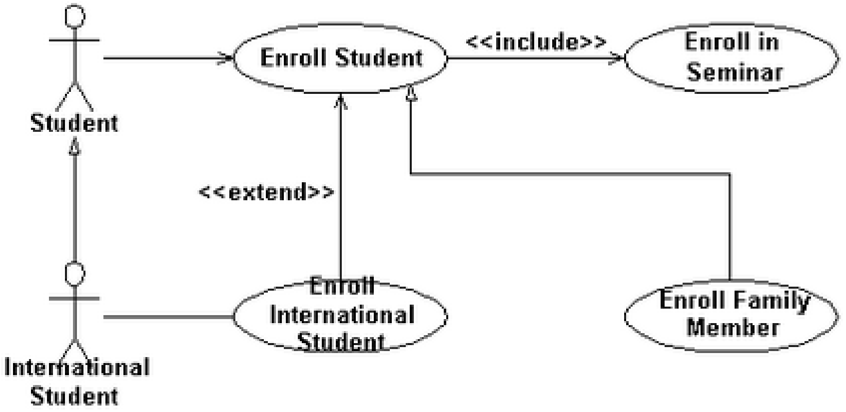
Online shopping.

1. Place Your Primary Actor(S) In the Top-Left Corner Of The Diagram
2. Draw Actors to The Outside Of A Use Case Diagram
3. Name Actors
4. Associate Each Actor with One Or More Use Cases
5. Actors Model Roles
6. Actors Don't Interact With One Another

<u>Relationships</u>

There are several types of relationships that may appear on a use case diagram:

- An association between an actor and a use case
- An association between two use cases
- A generalization between two actors
- A generalization between two use cases



Enrolling students in a university.

The task of building use cases for your new system is based on immediately identifying as many as you can, and then establishing a continuous loop of writing and refining the text that describes them. Along the way, you will discover new use cases, and also factor out commonality in usage.

You should feel comfortable proceeding to the next phases of the development process when you've achieved the following goals:

- You've built use cases that together account for all of the desired functionality of the system.
- You've produced clear and concise written descriptions of the basic course of action, along with appropriate alternative courses of action, for each use case.

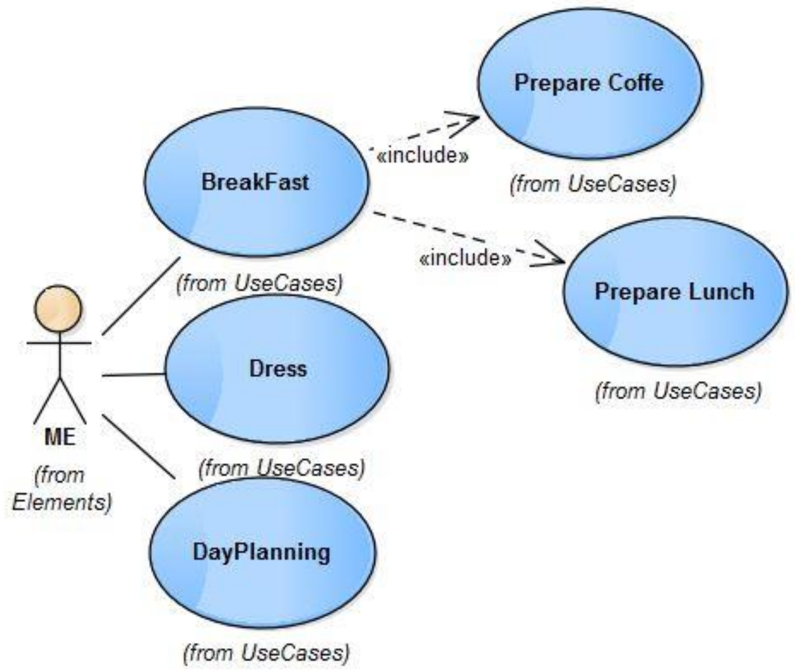
Architecture Specification – Diagram

The Top Use Case Modelling Errors

Contrary to the principles we just discussed are a number of common errors that we have seen students make when they're doing use case modeling on their projects for the first time. Our list follows.

- **Don't write functional requirements instead of usage scenario text**. Requirements are generally stated in terms of what the system shall do, while usage scenarios describe actions that the users take and the responses that the system generates.
- **Don't describe attributes and methods rather than usage**. Your use case text shouldn't include too many presentation details, but it should also be relatively free of details about the fields on your screens.
- **Don't write in the passive voice, don't use a perspective other than the user's**. A use case is most effectively written from the user's perspective as a set of present-tense verb phrases in active voice.
- **Don't omit use cases for not foreseen courses of action**. Basic courses of action are generally easier to identify and write text for. That doesn't mean, however, that you should put off dealing with alternative courses until, say, detailed design.
- **Don't spend a month deciding whether to use includes or extends**. simply pick one way of doing things and stick with it. Don't spin your Wheel.

TESTCASE:BREAKFAST - Use Case Diagram



In the Use case diagram the actors list the foreseen activities that are performed in the early morning.

Architecture Specification – Diagram

Block Diagram - Structure

A block diagram is a diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks.

The block diagram is a unified description of structure of elements and their relations.

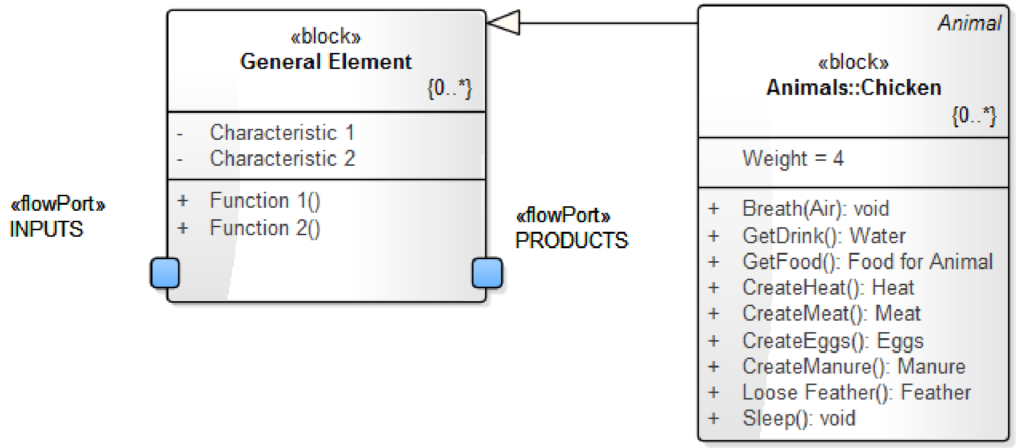
The representation of the elements can be supported by block diagrams. In these structures, in addition to the name of the element, there are often some combinations of the following fields:

● Operations: behavioural aspects assigned to the block. The operations reflect a subset of the allocated functions;

● Attributes: represent the quantifiable characteristics of a block, such as the physical and performance characteristics: weight, reliability, etc.

● Parts: they are the hierarchical composition of the block (the children).

● Flow ports: specifies what can flow in and out of a block.



Example for representation of elements with block diagram.

Architecture Specification – Diagram

Based on the characteristics of the place and the operator, the analysis can suggest which elements to insert, maintain or delete from the system, where to position them and, for the same element, which type / species to target.

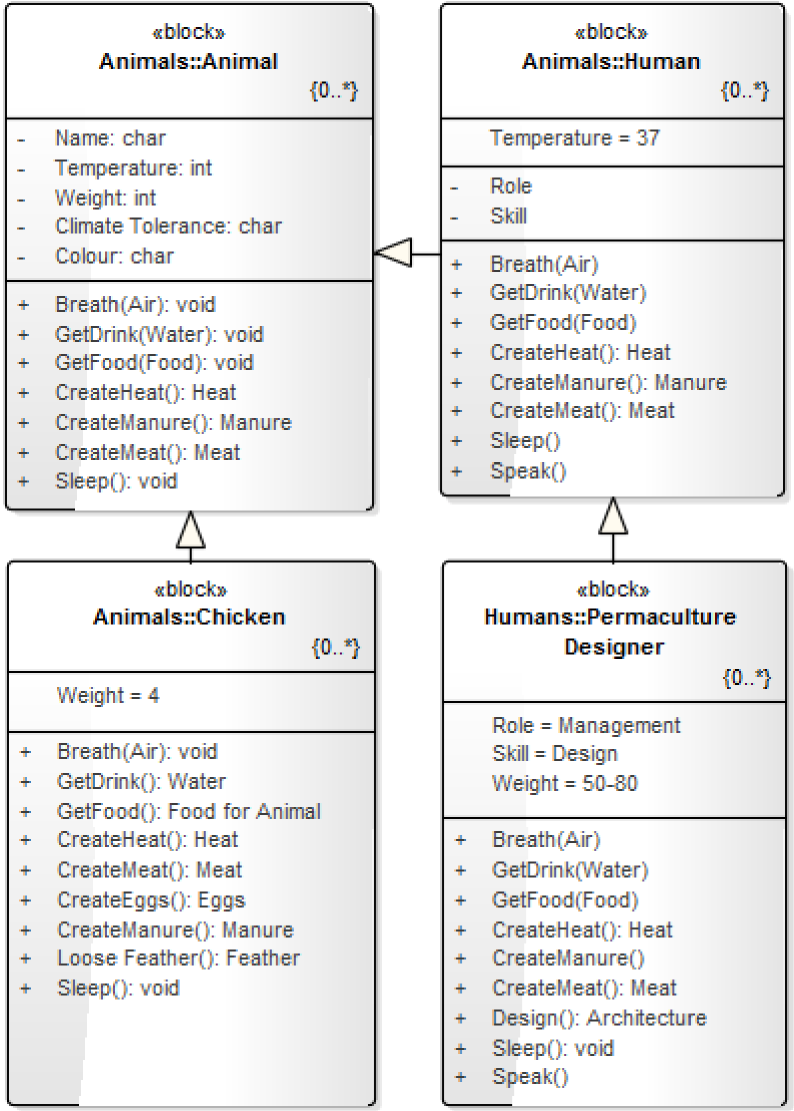
This analytical work should be done for each element, including the people who live in the system, in order to design an adequate and proportionate system for those who are responsible for management and to provide the necessary energy inputs.

The analysis of the elements helps us to create useful relationships between the different components of the system, which is exactly what happens in nature: the cycles are closed and the energy circulates in the systems fluidly producing an abundance of resources. A human system designed with a careful choice of well-positioned elements can work like a natural system requiring a minimum of energy for maintenance.

It is considered appropriate to underline how, although this tool can theoretically be used by the designer on the basis of a map or other IT tools, its application cannot be separated from a good observation of the place which is irreplaceable.

There is also a factor of variability and unpredictability to be taken into account when the design is passed on to implementation: having to do with living systems, there is no total possibility of control. We design a system as we would like it to be, with the awareness that the elements will interact with each other according to how they will have the opportunity to express themselves and the role they will spontaneously take in this system. Only by observing how the hen behaves in the orchard or the donkey in the olive grove, will we be able to understand how to re-modulate the design towards the ideal situation.

Hence the need for the cyclical design process which is repeated over time following observation of what has been achieved and reflection.



Architecture Specification – Diagram

Activity Diagram – Behaviour

An activity diagram is a behavioral diagram i.e. it depicts the behavior of a system. An activity diagram portrays the control flow from a start point to a finish point showing the various decision paths that exist while the activity is being executed

The diagram activities, sequences, collaborations, composite structures, interactions, and state charts represent the behaviours of the system. For example, an activity is represented by diagrams of control flow(s) between activities.

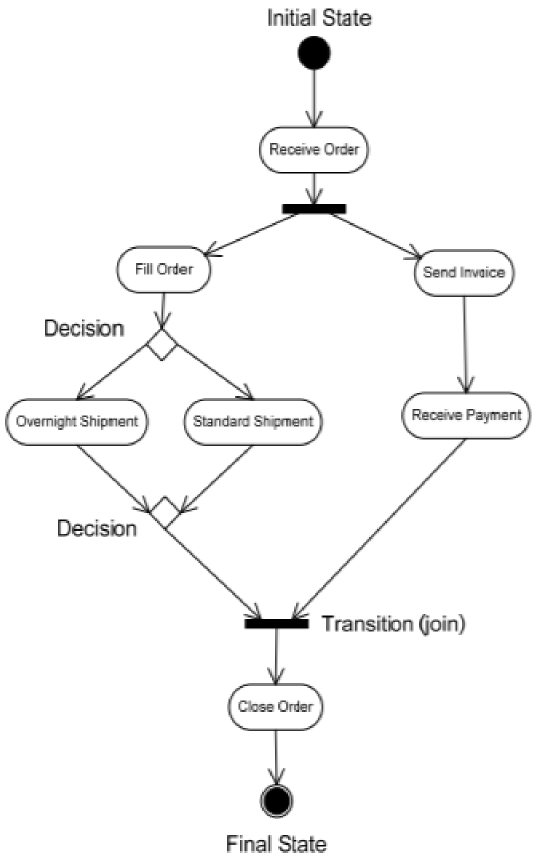


Figure Typical Activity Diagram (showing order processing)

Activity diagrams lay out the procedural flow of the activities or actions of a high level activity. Use Cases exist in most development projects, and concomitantly, activity diagrams should portray activities that enlighten the Use Cases at a more detailed level. Activity diagrams do not need to be always combined with Use Cases. They can be used independently and beneficially for business level functions, an example of which is modeling of online procurements. Activity diagrams model workflows that comprise a system. These diagrams are used along with other views, typically interactions, and states. Activity diagrams can also be used to analyze Use Cases. In this instance, actions are described in terms of their local interactions along with their associated timing. Activity diagrams give neither detail about objects and their behaviors nor objects and their collaborations (Fowler & Scott, 2004).

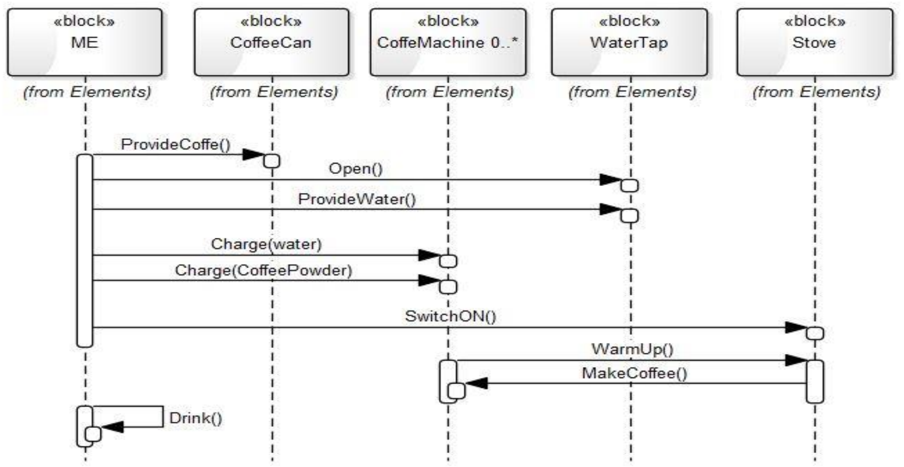
Architecture Specification – Diagram

Sequence Diagram - Behaviour

The sequence diagram captures the interaction between collaborating parts of a system. Part of the behavioural (logical architecture) representation set, the sequence diagram enables you to focus on triggering data and the resultant flow of control between components. This partial representation is particularly useful in understanding and confirming interactions early at each level of the system definition effort.

Sequence diagrams describe the succession of interactions between objects. Horizontal arrows represent messages or logic between objects. Similar to the format used in N-Squared Chart messages begin in the top left and proceed down in a step formation. Sequence diagrams organize and display the requirements that would be expressed in Use Cases. Sequence diagrams document objects and their interactions. These diagrams are useful for system architects and designer, and further, prove useful as a means to create continuity between project teams and individuals in (Bell, 2003).

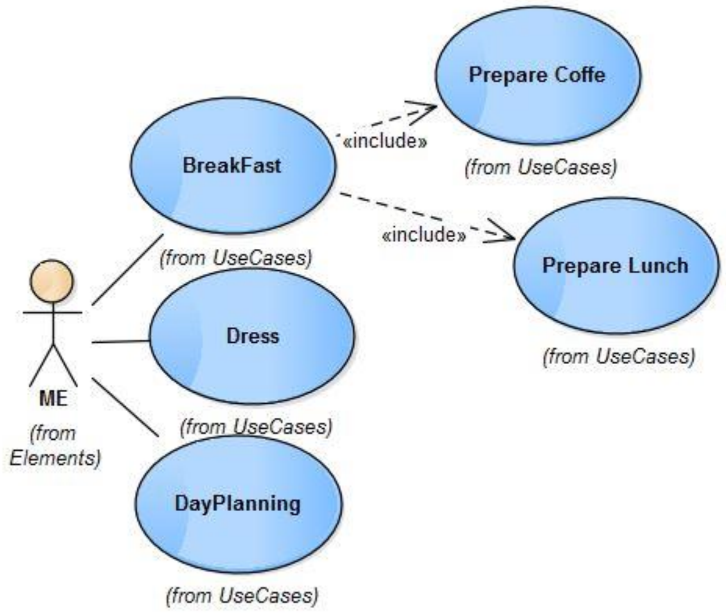
TESTCASE:BREAKFAST - Sequence Diagram



In the Sequence diagram the elements involved in the production of a cup of coffee are listed with specific links between them in relation to the performed functionalities.

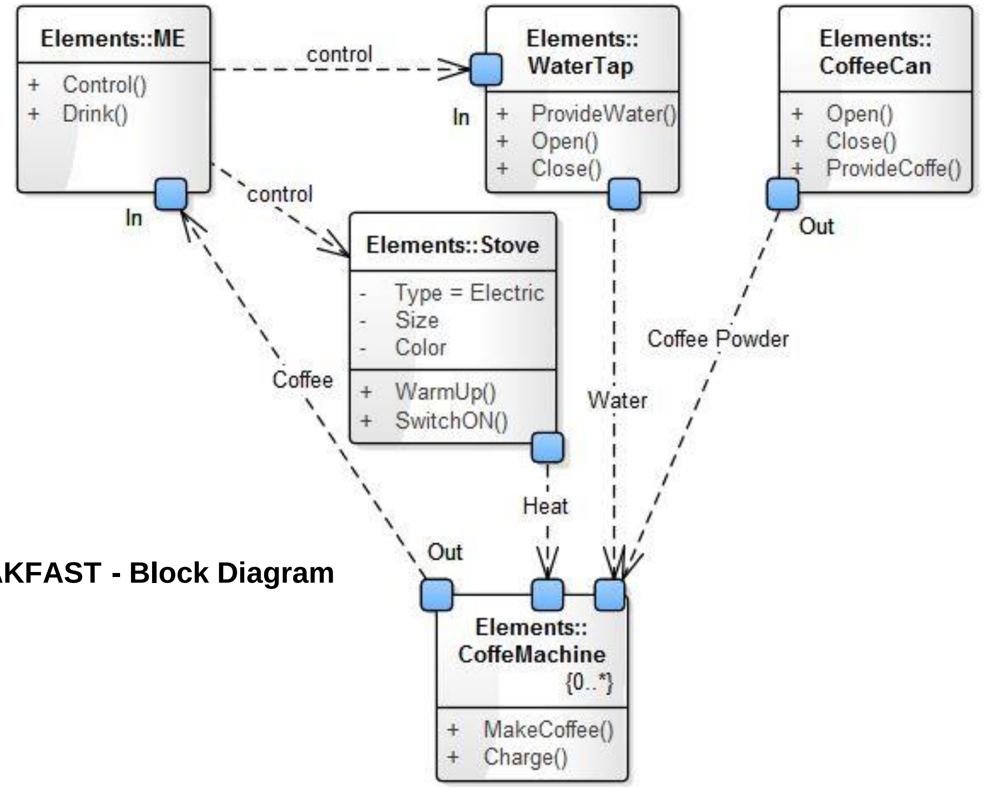
Architecture Specification – Diagram

TESTCASE:BREAKFAST - Use Case Diagram



In the Use case diagram the actors list the foreseen activities that are performed in the early morning.

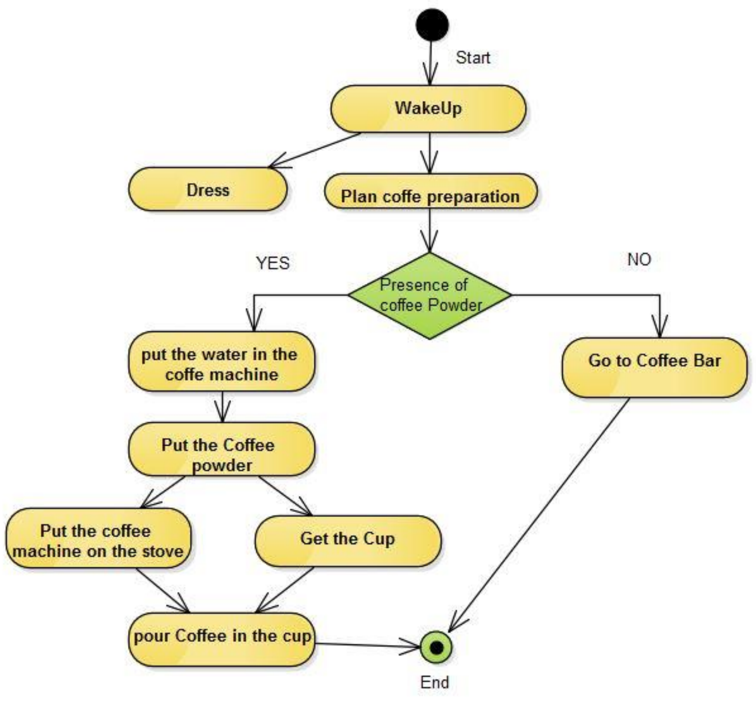
TESTCASE:BREAKFAST - Block Diagram



In the Block diagram the elements involved in the production of a cup of coffee are listed. Each Element provides the specification of Input, Output, functions and attributes.

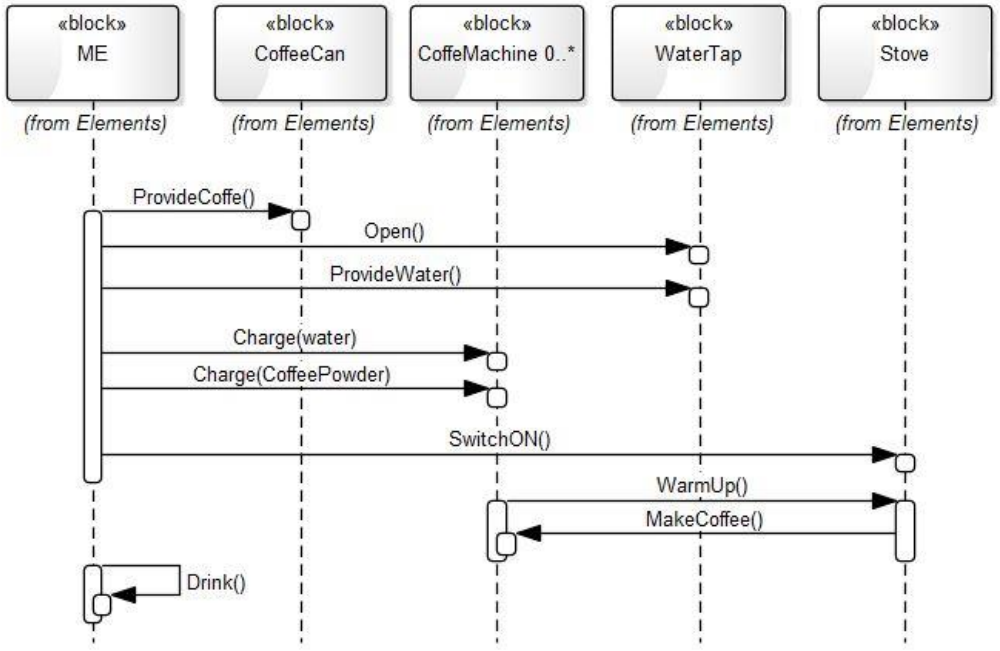
Architecture Specification – Diagram

TESTCASE:BREAKFAST - Activity Diagram



In the Activity diagram the activities involved in the production of a cup of coffee are listed.
Each activity has a link with another action or a decision. The logic flow has a start and end point and the only rules applicable is that in any case the end state is achieved.

TESTCASE:BREAKFAST - Sequence Diagram



Test Case Sequence Diagram

In the Sequence diagram the elements involved in the production of a cup of coffee are listed with specific links between them in relation to the performed functionalities.

Case studies – Food production

1 Food production

Henhouse

The chicken coop is the area dedicated to the hens, in which they stop, find shelter, lay eggs and feed. Once we have chosen the positioning of the chicken coop, we try to analyse how this element interacts with other elements, in a generic system.

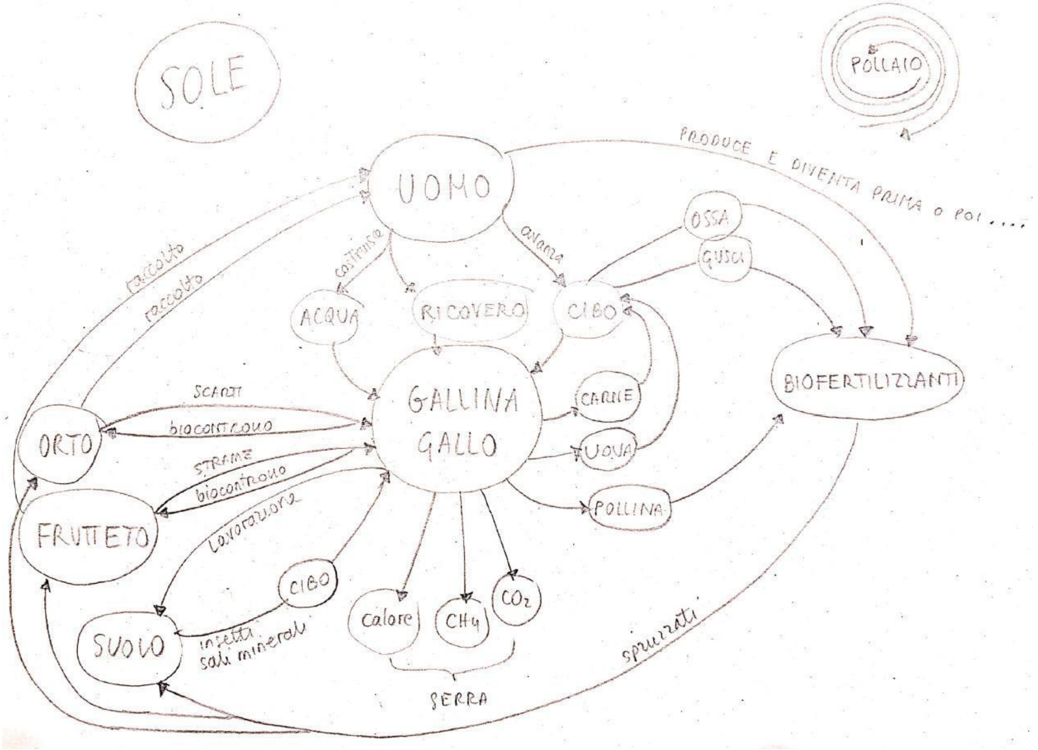
The following image summarizes the main connections that may exist in any case, in which products such as eggs, droppings and heat are directly produced from the hen house, which are directly connected to the home (for human consumption of eggs), respectively, to the production of fertilizer for the vegetable garden and the orchard, and the greenhouse that will benefit from the heat input.

Some connections will be guaranteed by human work (e.g. egg collection, biofertilizer production), therefore management activities must be taken into account in the design, which can be differentiated by type, quantity of energy to be used and frequency of performance.

Other connections will not require human energy (if not that of careful planning and management), such as the hatching activity of chickens in the vegetable garden and orchard which guarantees control of weeds and pests of crops.

In the system shown you can imagine a daily activity for the collection of eggs, for the opening and closing of the entrance door to the chicken coop, for the transfer of kitchen waste to the chicken coop.

You can also imagine a monthly cleaning activity of the chicken coop, a more occasional production of the biofertilizer and its distribution to the plants.



Functional diagram of a generic hen-house (From Paola XXX)

Case studies – Food production

<u>Orchard</u>

Another typical system is the orchard, which requires some human energy but in which many of the activities can be carried out by other self-regulating elements.

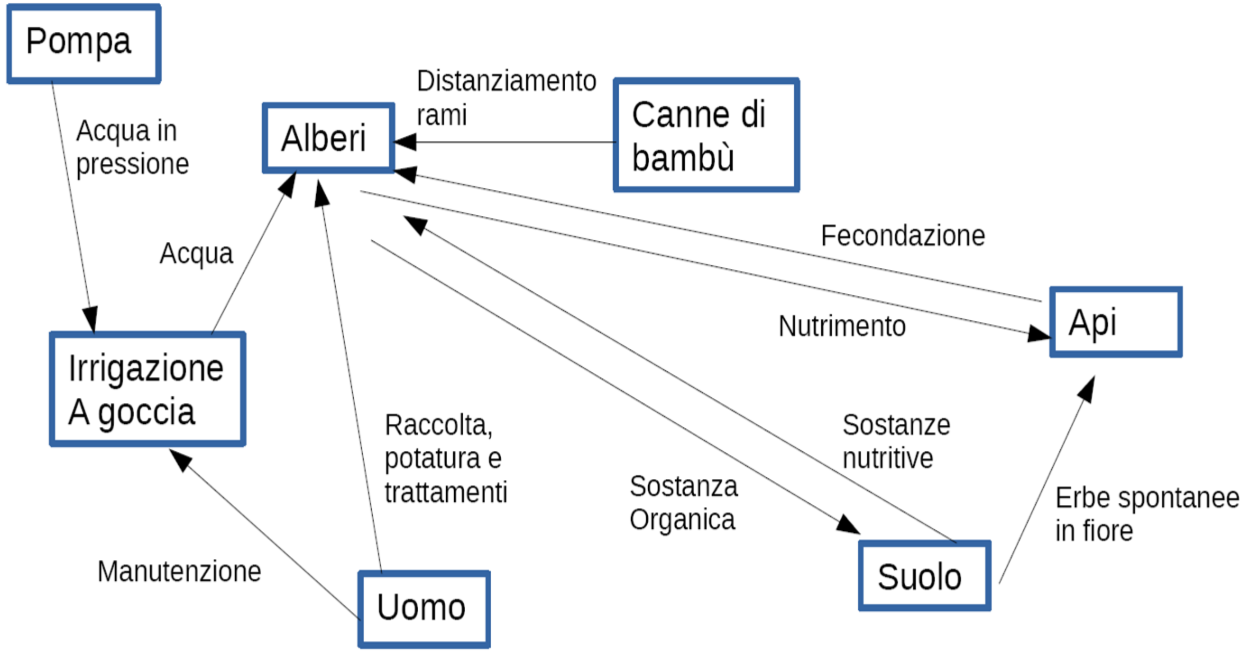
The following diagram simplifies the connections between different elements of the orchard system. Human activity in this case concerns the collection and care of trees, as well as the management of the irrigation system if provided.

Pollination and exchange of nutrients between soil and trees are naturally occurring.

The usefulness of visualizing similar connections, also through diagrams of this type, is manifold. First of all, in the design phase, the possibility of reasoning about relative positioning, to bring elements that support each other close. Secondly, the opportunity to identify in which ways it is possible to promote natural processes to the maximum in favour of the objectives set for the system, both through activities that require human energy, and through the inclusion of additional elements, which can catalyse / increase such processes.

For example, the fertilization process occurs naturally for fruit trees through the numerous pollinating insects present, however the installation of one or more hives, if compatible with the characteristics of the manager, increasing the pollination capacity can lead to an increase in productivity.

As well as some soil tillage practices (e.g. green manure) or the presence of grazing animals can make a big contribution to the production of organic matter in the soil, with all the advantages that derive from it.



Functional diagram of a generic orchard (From Davide XXX)

Case studies – Containment of vegetation for fire protection

With the following example, taken from a real case, we try to describe the cyclical design process (ORPA) that leads to the insertion of an element in the system through a precise architecture, and how this architecture is modified over time by the changes that occur (both due to the introduction of the element and the change in general conditions of the system and management).

1. Planning

It starts from a series of needs and characteristics of the system.
The primary requirement is that of a mowing of the ground for fire protection.
Other relevant elements in the system are the olive grove and the potential to plant aromatic plants for the production of essential oils.
The main features of the system are: scarce soil presence since the site is rocky (difficulty in making vegetable crops), long non-rainy periods in the hot season, rather rough terrain with difficult accessibility in some points, poor desire / possibility of the manager of one manual mowing also with the help of means (e.g. brush cutter).

Donkey grazing environment.

The possibility of inserting animals to fulfil the mowing function is identified, then an analysis is made of different types of animals to identify which of them can better fit into the system.
The donkey is identified as the most suitable animal for the site, so two heads are inserted in almost two hectares of land, with different grazing areas to which the animals’ access with a timed rotation.

Case studies – Containment of vegetation for fire protection

Grazing donkey.

Donkey grazing zones.

2 and 3 - Realization and observation

For three years from the time of insertion, the animals feed on only pasture of spontaneous vegetation. The land is largely in a wild state, with thick vegetation in some parts impenetrable.

The grazing of donkeys highlights the soil highlighting the morphological characteristics, the best paths are traced for moving.

The work of the manager is limited to the construction of light fences with electric wire, the daily filling of drinkers, the care of animal health when necessary.

What we are witnessing is an excellent job of cleaning the soil, some changes in spontaneous vegetation (aromatic and medicinal plants such as oregano and hypericum resurface and are strengthened), the appearance of mushrooms in some areas where they had never been observed, an indication of the activation of a certain soil microbiological activity.

Case studies – Containment of vegetation for fire protection

From the fourth year the system begins to change, in particular the thick vegetation initially present in the ground begins to decrease, since the regrowth capacity is not equal to the consumption of the pasture (in the long periods of summer drought the land remains as "embalmed", l vegetation growth stops or in any case is very slow).
The vegetation present in the soil that allowed two donkeys to feed for the first three years is no longer sufficient.
At the same time the manager is planting fodder trees and aromatic plants, with the need to protect them from grazing.

4. Reflection

The donkeys that in the first years of their presence have done an excellent job of containing the grass and unearthed untested portions of soil now seem to have become more "bulky" in the system, and a limitation to the possibility of freely introducing new plants and trees . Spontaneous vegetation cannot fully recover after their passage, it seems that the soil needs a longer rest time, however the containment of herbs for protection from fire continues to remain necessary. The pasture rotation plan and animal management should be reviewed.

Having to frequently rearrange the electric fences that quickly degrade begins to weigh on management, there is a need to create fixed fences where you can put animals when necessary.

Case studies – Containment of vegetation for fire protection

1a - Planning
The new starting point is a slightly pressed soil that does not totally support the feeding of two donkeys. An external supply of fodder and a place to stop the animals for the rest of the soil are necessary, while ensuring the containment of spontaneous vegetation where necessary.

2a and 3a - Realization and observation
In this second phase, the animals spend a good part of their time in a straw-fed paddok, and brought to graze on the rope to ensure minimal cleaning of the olive grove.
The management undergoes significant changes: purchase and management of straw bales, periodic cleaning of the barn, daily management of the movements of the animals in the periods in which they are brought to pasture with the rope.
The new management involves another change: the production of manure which was previously automatically distributed by the animals in the grazing areas, in the second phase is concentrated in the paddock and needs to be managed. On the one hand this requires human energy for the movement of manure and the formation of heaps, on the other hand this material is precisely what constitutes the soil of the small vegetable garden areas to be built near the house.

Heap of manure extracted from the paddok.

4a - Reflection

The management of straw bales is complex, since work is needed to move them and there is no adequate space for storage. Manure management is also tiring but provides a great deal of extremely useful material.

At this point of the experience, one wonders: donkeys continue to perform a useful function in the system or are they rather a limitation for new plantings?

The answer is that donkeys, however, relieve the management of the use of mechanical means to contain the grass, performing an excellent fire-fighting action in the extended area. In addition to this, other functions are identified for these animals (manure production, teaching, therapeutic) which make them still well connected with other elements.

For this reason, the design continues towards a scenario in which the donkeys will feed almost completely in the grazing areas, with a faster rotation and with the presence of fodder trees that in the meantime will have grown.

Case studies – Soil regeneration

If in the previous case, the regeneration of the soil was a secondary function, in the present case, regarding the reality of the *Ohminò* permaculture farm (Sardinia) it is the primary objective.
The company's objectives are to plant trees and shrubs with the multiple function of food production, creation of windbreak barriers and integration of pasture and landscape. The vegetation to be planted therefore has numerous species with various heights and functions to be combined in such a way as to be able to carry out the above functions effectively.

We are in an area where the soil starts from a situation of 85% of a large, clayey skeleton, with very little organic substance, and with a high risk of summer fire.

Since the soil is in poor condition, it is a priority to regenerate its fertility, so that the vegetation can develop at its best and already in the medium term the system can sustain itself with a minimum contribution of human energy.

The strategies chosen to achieve the company's objectives are therefore to increase biomass production, increase bacterial life in the subsoil and increase the infiltration and maintenance capacity of water and organic matter.

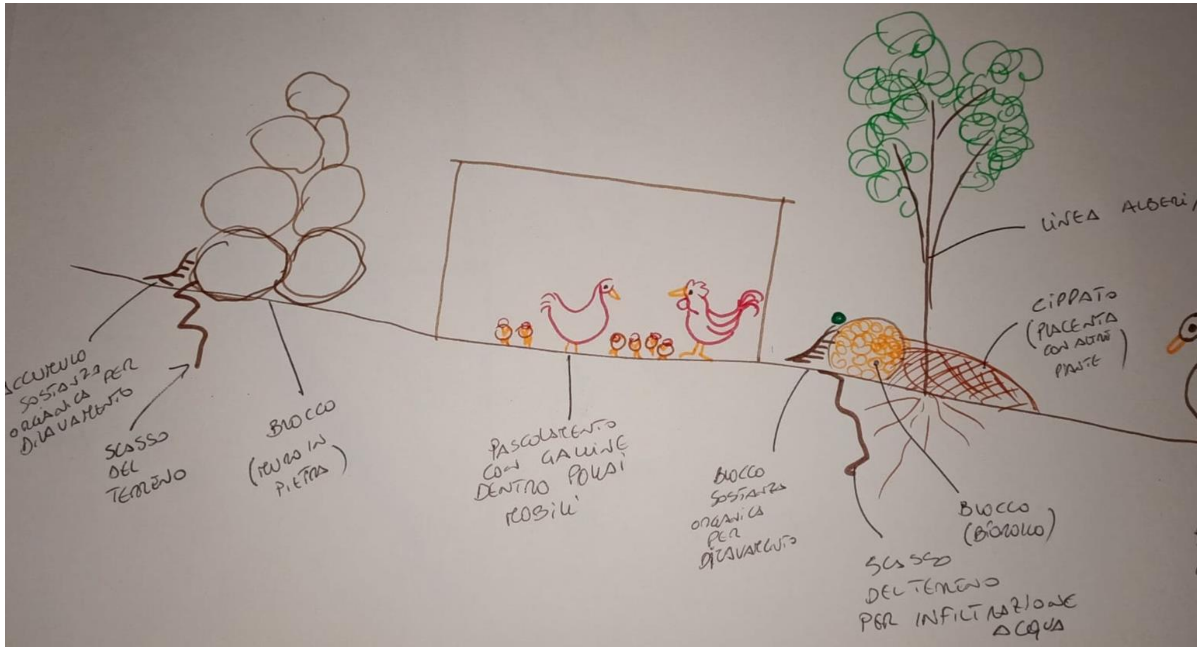
The implementation of these strategies is done through the combined action of structures and animals.

The starting point is a stone wall, which acts as a condenser for the humidity present in the air which in this way is conveyed around the wall, where the soil remains moist. Just in this area animals like donkeys and sheep come into play, which are induced to stop near the wall where they find shelter from the sun and food in the mangers.

The wall is a point of accumulation of humidity and also of organic substance, which increases the water infiltration capacity of the soil, represents a nucleus from which soil fertility is created through the combined action of different elements. Over a couple of years, these areas where organic matter is abundant are suitable for the planting of new vegetation, so trees are planted along the line of the wall.

To block the water and organic matter accumulated in the strip of soil near the wall and prevent rain washout, another block is created in the downstream part, with functions similar to that of the wall described above. This block can be a bio-roll (a cylindrical cluster of branches and woody vegetation), which in addition to blocking the material is a vehicle for humidity and accumulation of organic matter.

Case studies – Soil regeneration



Sketch of the techniques used for soil regeneration.

The fact that different types of structures are built (dry stone walls or bio-walls) depends on the material available at that time and the availability of manpower.

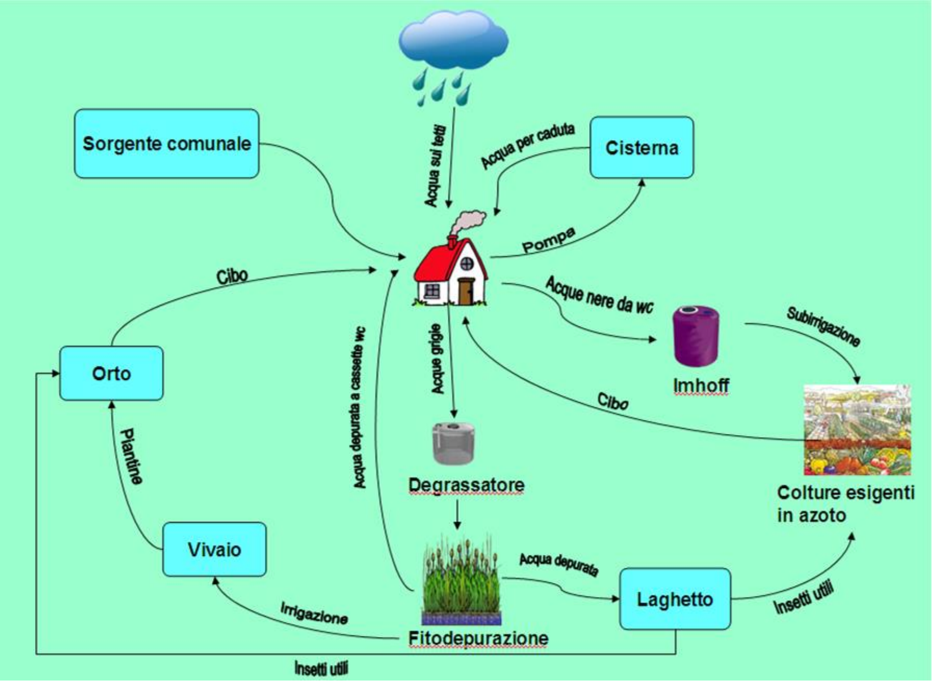
In the space between the wall and the bio-roll, "chicken tractors" keep the grass at bay (assisted by geese) and load the soil with organic matter. So, over another two years, the strip adjacent to the bio-roll is ready for the planting of other trees.

Every year blocks and planted vegetation are created according to the sequence described above, so the areas of fertile soil are expanding year by year and a large number of plants, chosen from local and non-local varieties, but all suitable for the climatic belt of the area, enrich the landscape and production heritage of the farm

Case studies – Domestic water recovery

The last illustrated case represents a system for the recovery and reuse of water in the home, in a system that tries as much as possible to retain and enhance this resource in places where rain is scarce is particularly precious.
The sources of water supply for the example house are two: the source managed by the municipality and rainwater.
A suitable system for conveying the downpipes with an attached pump ensures that the water collected from the roofs is sent to a cistern which is at a sufficiently higher altitude than the house, so that the water can then arrive here by fall.
The waste water of the house is differentiated according to the users by means of separate drain pipes: the black water from the toilet and the gray water, which is the least "dirty", deriving from all the other users.
The black water passes from the Imhoff pit to be clarified but remains loaded with nutrients, in particular nitrogen, then goes into sub-irrigation (to avoid contamination) by free fall to crops that have a strong demand for this element.
The grey waters, after degreasing, are purified through a Phyto-depuration system, so they become suitable for the irrigation of the vegetable garden, the nursery and to be reused in the house, exclusively in the toilet cisterns.

In such a system, the bulk of human energy must be used in the construction of the plants, which can only be done in case of new construction or major renovation.
Once the plant layout is given, the main job is that of maintenance, in particular of the pumps, and of the ordinary management of the plants of phyto-purification, which generally require an annual mowing (which can constitute fodder for large animals, or biomass in general). , and the pond.
The rest of the activities falling within the links represented in the image concern natural processes or human activities that would still be done for the management of agricultural production.



Functional diagram for water recovery.

Schedule and Budget

The **schedule** (or timeline) is a vital tool to ensure that the project team knows what they need to do.
The **budget** represents the number of resources required by the project.
The schedule and budget can be tied in a single integrated product. The two concepts are different. The schedule shows the activities required to build the deliverables of the project. The budget shows how much money the project will require.
These are two fundamental processes required for the project success.

- If a project is behind its schedule it is generally over budget as well.
- If a project is over budget it is usually trending over its deadline as well.
- If you have underestimated the amount of work, you are generally going to have underestimated both the schedule and the budget element.
- The effort hours applied from human resources on the project are going to impact both the schedule and the budget.
- They are two integrated elements of the overall triple constraint, which links the schedule, budget and project scope. If the scope of the project is increased (or decreased), the schedule and budget elements need to increase (or decrease) as well.

In many cases, these two deliverables need to be worked on in parallel. As you gather information around scope and deliverables, you will need to start laying out an overall timeline and budget so that you can get your hands around estimated effort and duration. As you get more “definition” information, you will fill in more detail on the schedule. When the deliverables, scope, assumptions and approach are complete, you should have enough information in the schedule to estimate the necessary budget, effort and duration

The **project management triangle** (called also the *triple constraint*, *iron triangle* and *project triangle*) is a model of the constraints of project management that underlines the dependancy between scope, budget and timing. It contends that:

1. The **quality** of work is constrained by the project's budget, deadlines and scope (features).
2. The **project manager** can trade between constraints.
3. Changes in one constraint necessitate changes in others to compensate or quality will suffer.

For example, a project can be completed faster by increasing budget or cutting scope. Similarly, increasing scope may require equivalent increases in budget and schedule. Cutting budget without adjusting schedule or scope will lead to lower quality.

Schedule

The successful achievement of the proposed objective and scope are dependant of the completion of the activities.

For each activity the dependencies in between can be determined, which in turn allow resources and time scales to be estimated at a high level for the whole project and in detailed for each task.

Which is the benefit to produce a detailed schedule?

- Defines the overall project approach
- Produces a customized work breakdown structure specific to the project
- Creates an estimate of the total cost of the project and the associated target completion dates
- Identifies the major project control points
- Identifies, at a high level, the resources required to implement the project

What is a schedule?

A component of the project management plan that establishes the criteria and the activities for developing, monitoring, and controlling the schedule. The schedule management is based upon the needs of the project, and includes appropriate control thresholds.

For example, the schedule management plan can establish the following:

- **Project schedule model development**. The scheduling methodology and the scheduling tool to be used in the development of the project schedule model are specified.
- **Level of accuracy.** The acceptable range used in determining realistic activity duration estimates is specified and may include an amount for contingencies.
- **Units of measure.** Each unit used in measurements (such as staff hours, staff days, or weeks for time measures, or meters, litres, tons, kilometres, or cubic yards for quantity measures) is defined for each of the resources.
- **Organizational procedures links.** The WBS provides the framework for the schedule management plan, allowing for consistency with the estimates and resulting schedules.
- **Project schedule model maintenance.** The process used to update the status and record progress of the project in the schedule model during the execution of the project is defined.
- **Control thresholds.** Variance thresholds for monitoring schedule performance may be specified to indicate an agreed-upon amount of variation to be allowed before some action needs to be taken. Thresholds are typically expressed as percentage deviations from the parameters established in the baseline plan.
- **Reporting formats.** The formats and frequency for the various schedule reports are defined.

Schedule and Budget

Activity List

The activity list is a comprehensive list that includes all schedule activities required on the project. The activity list also includes the activity identifier and a scope of work description for each activity in sufficient detail to ensure that project team members understand what work is required to be completed. Each activity should have a unique title that describes its place in the schedule, even if that activity title is displayed outside the context of the project schedule.

Activity Attributes

Activities, distinct from milestones, have durations, during which the work of that activity is performed, and may have resources and costs associated with that work. Activity attributes extend the description of the activity by identifying the multiple components associated with each activity. The components for each activity evolve over time. During the initial stages of the project, they include the activity identifier (ID), WBS ID, and activity label or name, and when completed, may include activity codes, activity description, predecessor activities, successor activities, logical relationships, leads and lags, resource requirements, imposed dates, constraints, and assumptions.

Activity attributes can be used to identify the person responsible for executing the work, geographic area, or place where the work has to be performed, the project calendar the activity is assigned to, and activity type such as level of effort (often abbreviated as LOE), discrete effort, and apportioned effort. Activity attributes are used for schedule development and for selecting, ordering, and sorting the planned schedule activities in various ways within reports. The number of attributes varies by application area.

The following sequence illustrates the activities executed during Project Schedule and Budgeting :

- Determine Project Approach
- Determine Processes and Activities
- Determine Process and Activity dependencies
- Establish resource requirements
- Prepare project Schedule
- Prepare project budget Estimate
- Document schedule assumptions
- Review project schedule and budgeting

!	%		Start	Due	Occurs	Cat.	€	Travel	Title ^
5	3%		10/1/2015	7/30/2020					Project - Permaculture Farm
7	0%		10/1/2015	7/30/2020					Task 0 - Project Management
7	0%		10/1/2015	7/30/2020			150		banking
7	0%		10/1/2015	7/30/2020			40		communication
7	0%		10/1/2015	7/30/2020			40	+	documentation
7	0%		10/1/2015	7/30/2020			300		Meetings
7	0%		10/1/2015	7/30/2020			1500		project management
9	0%		10/1/2015	7/30/2020					Task 1- Project preparation
6	0%		1/1/2016	7/30/2020					Task 2 - Main Activity 1
4	1%		1/1/2016	7/30/2020					Task 3 - Main Activity 1
8	25%		10/1/2015	7/30/2020					Task 4. - Evaluation and Dissemination

Determine Project Approach: The ideal situation is to have a proven process on which to base the tasks for the project. The whole project can be divided in different project phase for easy the process. Refer to chapter 7.4.2

Determine Processes and Activities: For each Phase defined in the Project Life Cycle process, determine the steps required to complete the Phase.

This requires a high-level Work Breakdown Structure (WBS) for the overall project. A WBS is a "family tree" of the project activities required to deliver the end product or service. It is usually broken down into levels (operational processes), activities (sub-processes) and tasks.

Schedule and Budget

Determine Process and Activity dependencies: Chart the sequence of the Phases and steps to reflect the dependencies inherent in the project. Define dependencies and dependency type (e.g. Phase to Phase, step to step, etc.) between activities.

Document these relationships in a chart. Ensure that all dependencies either with any other projects are identified.

Estimate Effort: Once this has been done, estimate the resources.

Using base estimating guidelines/metrics, produce an initial top-down estimate for the overall project and apportion to the component Phases and to the identified activities.

Here a preliminary dual analysis of the system from a time and cost perception should take place.

The specification for resources and related usage is estimated as for contract personnel, facilities, equipment, materials and supplies.

A time line and cost estimate for the project can then be developed.

The estimate given at this point should reflect the amount of work to be done to complete the project.

Establish resource requirements:

Using the estimate for the overall project, define an initial requirement for resources.

For the project schedule it is sufficient to estimate the number of each type of resources required (e.g. the role or function) rather than specific people or suppliers.

Also identify other resources required for the project such as, facilities, equipment, tools, materials, etc. Record all assumptions and identified issues.

Human Resource Management Plan

The human resource management plan, a part of the project management plan, provides guidance on how project human resources should be defined, staffed, managed, and eventually released. The human resource management plan and any subsequent revisions are also put into the Develop Project Management Plan process.

The human resource management plan includes, but is not limited to, the following:

• **Roles and responsibilities**. The following should be addressed when listing the roles and responsibilities needed to complete a project:

○ *Role*. The function assumed by or assigned to a person in the project. Examples of project roles are civil engineer, business analyst, and testing coordinator. Role clarity concerning authority, responsibilities, and boundaries should also be documented.

○ *Authority*. The right to apply project resources, make decisions, sign approvals, accept

deliverables, and influence others to carry out the work of the project. Examples of decisions that need clear authority include the selection of a method for completing an activity, quality acceptance, and how to respond to project variances. Team members operate best when their individual levels of authority match their individual responsibilities.

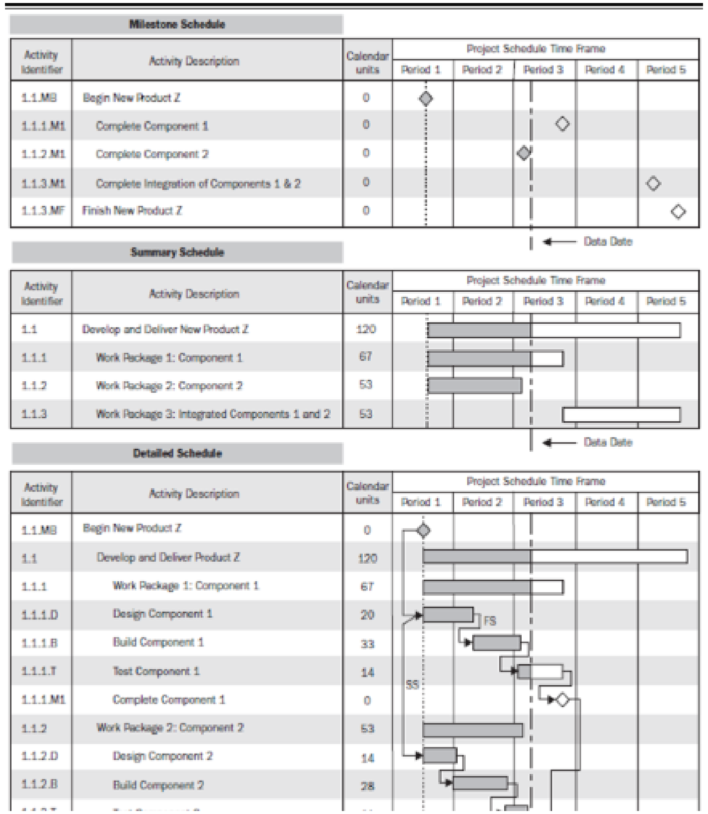
○ *Responsibility*. The assigned duties and work that a project team member is expected to perform in order to complete the project's activities.

○ *Competency*. The skill and capacity required to complete assigned activities within the project constraints. If project team members do not possess required competencies, performance can be jeopardized. When such mismatches are identified, proactive responses such as training, hiring, schedule changes, or scope changes are initiated.

Human Resource Management Plan

- **Project organization charts**. A project organization chart is a graphic display of project team members and their reporting relationships. It can be formal or informal, highly detailed or broadly framed, based on the needs of the project. For example, the project organization chart for a 3,000-person disaster response team will have greater detail than a project organization chart for an internal, twenty-person project.
- **Staffing management plan**. The staffing management plan is a component of the human resource management plan that describes when and how project team members will be acquired and how long they will be needed. It describes how human resource requirements will be met. The staffing management plan can be formal or informal, highly detailed, or broadly framed, depending upon the needs of the project. The plan is updated continually during the project to direct ongoing team member acquisition and development actions. Information in the staffing management plan varies by application area and project size

Schedule and Budget



Prepare project Schedule: Develop an initial schedule of project activities.
Record all assumptions and issues that have been identified in previous steps and activities.
The project schedule must include the following components:

- Project Activity Work Breakdown Structure (WBS)
- Activity Constraints (e.g. Must start on, Must finish on, etc.)
- Estimated Effort (Work) and Duration
- Scheduled Start and Finish Dates for Each Activity
- Resources Assigned to Each Activity
- Resource Availability

The project schedule is documented in Gantt chart format.

How to present the schedule

Although a project schedule model can be presented in tabular form, it is more often presented graphically, using one or more of the following formats, which are classified as presentations:

Although a project schedule model can be presented in tabular form, it is more often presented graphically, using one or more of the following formats, which are classified as presentations:

- **Bar charts.** These charts, also known as Gantt charts, represent schedule information where activities are listed on the vertical axis, dates are shown on the horizontal axis, and activity durations are shown as horizontal bars placed according to start and finish dates. Bar charts are relatively easy to read, and are frequently used in management presentations. For control and management communications, the broader, more comprehensive summary activity, sometimes referred to as a hammock activity, is used between milestones or across multiple interdependent work packages, and is displayed in bar chart reports.

- **Milestone charts.** These charts are similar to bar charts, but only identify the scheduled start or completion of major deliverables and key external interfaces.
- **Project schedule network diagrams.** These diagrams are commonly presented in the activity-on-nodediagram format showing activities and relationships without a time scale, sometimes referred to as a pure logic diagram or presented in a time-scaled schedule network diagram format that is sometimes called a logic bar chart, as shown for the detailed schedule. These diagrams, with activity date information, usually show both the project network logic and the project's

critical path schedule activities. This example also shows how each work package is planned as a series of related activities. Another presentation of the project schedule network diagram is a time-scaled logic diagram. These diagrams include a time scale and bars that represent the duration of activities with the logical relationships. It is optimized to show the relationships between activities where any number of activities may appear on the same line of the diagram in sequence.

Schedule and Budget

A budget is a financial plan for a defined period. It may include planned sales volumes and revenues, resource quantities, costs and expenses, assets and cash flows. it is the expression of the strategic plans of activities in measurable terms.

A budget is the sum of some resource not only money, allocated for a particular purpose and the summary of intended expenditures along with proposals for how to meet them.

The aim of the budget is to:

1. Provide a forecast of Input and output flow.
2. Enable the actual operation of the project to be measured against the forecast.
3. Establish the cost constraint for a project, program, or operation.

Activity cost estimation for the various project activities is aggregated into their associated category or work package.

Since the cost estimates that make up the cost baseline are directly tied to the schedule activities, this enables a time-phased view of the project resources management.

Cost estimates can be presented in summary form or in detail. Costs are estimated for all resources that are required by the Project breakdown.

The budget describes how the project costs will be planned, structured, and controlled. The cost management processes and their associated tools and techniques are documented in the cost management plan.

Schedule and Budget

The budget shall specify the following:

- **Units of measure.** Each unit used in measurements (such as staff hours, staff days, weeks for time measures; or meters, litres, tons, kilometres, or cubic yards for quantity measures; or lump sum in currency form) is defined for each of the resources.
- **Level of accuracy.** The acceptable range (e.g., ±10%) used in determining realistic activity cost estimates is specified, and may include an amount for contingencies;
- **Control thresholds**. Variance thresholds for monitoring cost performance may be specified to indicate an agreed-upon amount of variation to be allowed before some action needs to be taken. Thresholds are typically expressed as percentage deviations from the baseline plan.
- **Rules of performance measurement**. Earned value management (EVM) rules of performance measurement are set. For example, the budget plan may:
    1. Define the points in the project plan at which budget control will be performed;
    2. Specify tracking methodologies between schedule, project breakdown decomposition
    3. Evaluation and assessment, plan and strategy
- **Reporting formats.** The formats and frequency for the various cost reports are defined.
- Process descriptions. Descriptions of cost management processes is documented.
- Additional details. Additional details about cost management activities include, but are not limited to:
    1. Description of strategic funding choices,
    2. Procedure to account for fluctuations in currency exchange rates, and
    3. Procedure for project cost recording.

Estimate Costs

Cost estimates are a prediction that is based on the information known at a given point in time. Cost estimates include the identification and consideration of costing alternatives to initiate and complete the project. Cost trade-offs and risks should be considered, such as make versus buy, buy versus lease, and the sharing of resources in order to achieve optimal costs for the project.

Schedule and Budget

Determine Budget is the process of aggregating the estimated costs of individual activities or work packages toestablish an authorized cost baseline. The key benefit of this process is that it determines the cost baseline against which project performance can be monitored and controlled. A project budget includes all the funds authorized to execute the project.

Prepare Project Budget Estimate:

On the basis of the initial activity and resource schedule, produce a spreadsheet showing cumulative project costs over time. Include the following costs at a minimum:

- Human Resources
    - Team expenses
    - Team training
- Contract services
- Facilities
- Equipment
- Material
- Transport
- Telecommunication
- Outsource costs
- Regulatory expenses
- Miscellaneous costs
- Customer training

Determine the budget required for the project based on the spreadsheet.

As with the preliminary – project effort estimate, it is important to document and communicate to all interested parties that this budget estimate for the overall project is only a preliminary. The budget estimate given at this point should reflect the project team’s certainty of the amount of work needed to complete the project. It is also important to communicate that this budget estimate is revised at the end of subsequent steps and that the accuracy will improve as the project progresses.

Cost estimates need to be developed for the overall project and for each Phase. Cost estimating also includes identifying and considering various costing alternatives for various stages of the project or specific deliverables.

Cost estimates must cover all resource categories that will be charged to the project (e.g., effort, materials, supplies, etc.) in addition to special categories such as contingency reserves. Supporting detail for the estimates, such as assumptions and constraints should be included.

A budget plan may be formal or informal, highly detailed or broadly framed based on the needs of the project.

Here below the budget of a project is presented:

							Task 1	Task 2			Task 3			Task 4
							1.1	2.1	2.2	2.3	3.1	3.4	3.5	4.3
BUDGET LINES	UNITS	unit cost	No. of units	TOTAL COST	request	Task								
BUDGET LINE 1 (e.g. , wages to														
Project Management	months	12	300.00	3,600.00	3,600.00	1.1	3600							
Project Design on Workshops	months	4	300.00	1,200.00	1,200.00	1.2		1200						
Project Development	months	8	150.00	1,200.00	1,200.00	2.3			1200					
Human resources	months	3	150.00	450.00	450.00	3.5.1				450	450			
Woofers	unit	2	400.00	800.00	0.00	all								
Volunteers	unit	2	400.00	800.00	0.00	all								
Subtotal 1					19,200.00									
BUDGET LINE 2 (e.g. travels and transportations)														
Mission for Project settlement	Unit	1	400.00	400.00	400.00	1.3	400							
Mission for Scolarships on Per	Unit	1	400.00	400.00	400.00	3.5.3					400			
Local transport	Unit	1	200.00	200.00	200.00		200							
Subtotal 2					3,400.00									
BUDGET LINE 3. (e.g.														
Food for Technician for area: V	Day	30	10.00	300.00	300.00	3.1.4								
Material for Workshop - area:	Unit	1	2000	2,000.00	2,000.00	3.3.3						2000		
Equipment (Laptop, Software,	Unit	1	2000	2,000.00	0.00	3.1 -								
Tools and machineries for Wor	Unit	1	2000	2,000.00	0.00	3.1 -								
Subtotal 3					9,200.00									
BUDGET LINE 4 (e.g. purchase,														
Material for area: Water - Harve	Unit	1	2000	2,000.00	2,000.00	3.1.4								
Material for area: Energy - Pho	Unit	1	2000	2,000.00	2,000.00	3.2.4								
Material for area: Building - Co	Unit	1	2000	2,000.00	2,000.00	3.4.3							2000	
Subtotal 6					7,700.00									
7. OTHER COSTS (e.g. overheads costs, bills, rent, management and secretary costs, administrative charges, stationery etc)														
Administrative charges	Unit	1	200.00	200.00	200.00		200							
Visa and passports	Unit	1	200.00	200.00	200.00		200							
Money transfer and bank	Unit	1	200.00	200.00	200.00		200							
Stationery	Unit	1	50.00	50.00	50.00		50							
Phone	Unit	1	50.00	50.00	50.00		50							
Subtotal 7					700.00									
TOTAL					47,900.00		4900	2700	1950	450	9950	6300	4300	500

Schedule and Budget

In parallel with the cost evaluation the related schedule have been produced and here below reported:

Actions	Nov	Dic	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Set	Ott	Task Description	Budget
1													1. Project Settlement	4900
1.1													Project management	
1.2													Networking and local survey	
1.3													Thematics KickOff	
2													2. Design and development	5300
2.1													Design	
2.2													Development	
2.3													Selection of personnel	
3													3. Thematic development	20550
3.1													Permaculture	
3.2													Water	
3.3													Energy	
3.4													trainings	
3.5													Building	
4													4. Presentation and assessment	500
4.1													Events	
4.2													Conference and Fundraising	
4.3													Assessment	

<u>Activity Resource Requirements</u>

Activity resource requirements identify the types and quantities of resources required for each activity in a work package. These requirements then can be aggregated to determine the estimated resources for each work package and each work period. The amount of detail and the level of specificity of the resource requirement descriptions can vary by application area. The resource requirements documentation for each activity can include the basis of estimate for each resource, as well as the assumptions that were made in determining which types of resources are applied, their availability, and what quantities are used.

Random assembly – Design by assessing the results of random combination

It is a very simple method that is based on assembling elements and positioning strategies in a completely random way. Just make a list of elements and arrange them in a circle around a series of possibilities of dislocation, mark the connections in a completely random way (without being influenced by various conditions), and then check the result obtained.

It is possible that solutions that would never have been thought of, or even not very rational, come out, however the method brings to light creative possibilities, which can be evaluated in terms of functionality.
It is a work backwards compared to that done with the analysis of the elements, which starts from the assembly and then passes on to the analysis of the benefits that derive from it.
The advantage of the method is to offer the possibility of sifting out unusual combinations, which perhaps reason or a consolidated approach to finding solutions would make us discard immediately, and which may perhaps prove valid.

House
Storage box
Animal shelter
Compost heaps
Pound
Windbreak
Fence

ATTACHED TO
AROUND
UNDER
BESIDE
OVER
ON
IN
CONTAINING
…

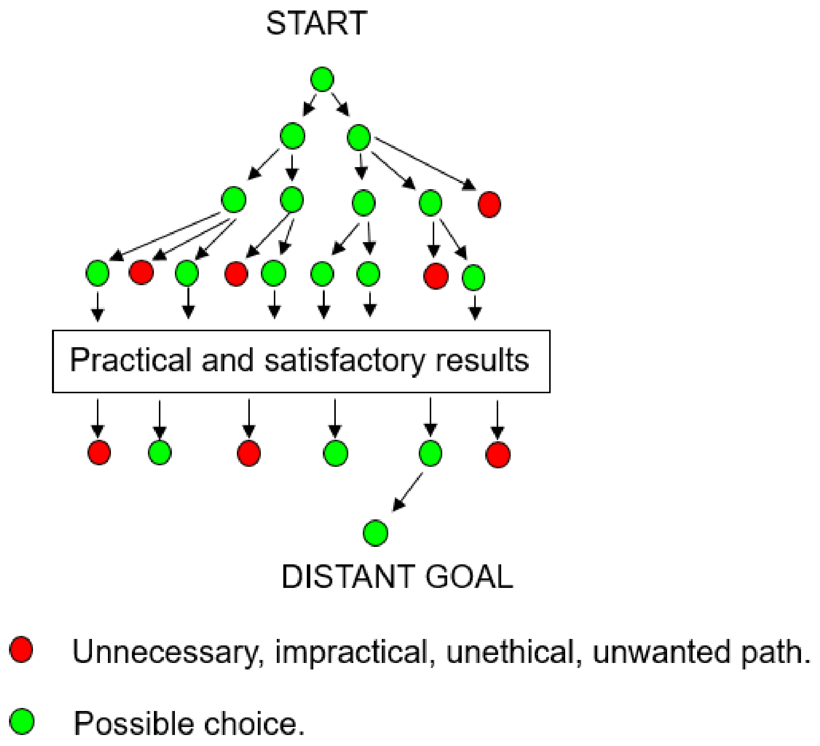
Glasshouse
Trellis
Swales
Caves
Garden
Stable
Wood oven

Example of random assembly selection.

Options and decisions – Design as a selection of option of pathways

Each design has different evolution possibilities, what determines the possible options are the stated objectives and characteristics in terms of capacity, lifestyle and resources, of those who commission the project.
For the design it is necessary to make a series of choices regarding, for example, the types of crops to be planted, economic or time and energy investments of people, congruity with management skills / possibilities, opportunities inside or outside the site.
There are therefore multiple possible options that can initially make the situation confusing and complex, that's why the design can help to set at least some starting points, choosing options from which other possible options will arise.
The open options generally derive from general decisions, such as "Cultivating the land by taking care of it". From this choice derive other possible options that may concern things such as the non-use of chemicals and erosion control; then the other resulting options will lead to choices also on the basis of the costs and energy available, in the short and long term.
This process can be better understood if represented graphically, as illustrated in the figure below.

By evaluating the options according to the decisions, many possible scenarios will be opened, which is advantageous considering that in times of uncertainty like this it is better to have more cards to play.



Possible options. (From Permaculture ; Designer handbook. Bill Mollison).

Project Submission and specification – Presenting a project

The specification of a project can be shared to be evaluated by customers, specific evaluation committees or anyone who could be interested in it.
It is useful to have a clear **check list** and approach to organize all produced information to allow a clear and easy comprehension of the project proposal. A table displayed below aims to summarize the project documents or deliverables with a specific and brief description of the content.
Such a table should be comfortable to read, and it should be easy for the reader to find what has been described in the previous chapters of the present coursebook.

Id	Name	Element
1	Travel Diary	• Blog, agenda or diary, map and articles
2	Project Document	Abstract of the project with the resume of all the essential information ● Project title, Description of the project, Main sector (social, agricultural, ...) ● Context, Objectives (concise reference), Expected Results, Project Duration, ● Partners or collaborators, Place of construction, Legal ownership of the land ● Number of people who will benefit, Total cost, Funding sources, Attachments
3	Project Diary	Observations • Dreams and needs, Climate, Resources, Animal & Plant, Guild, Pattern, Social context, Positive and negative (yin and yang)
4	Technical Context	● Site plan, Climate study, Zone and sector analysis ● Resources, strengths and critical points, Logistics (places, routes, loads, frequency of use)
5	Method	Method, approach and process
6	Project Specification	The definition of: Scope ⍰ Objectives ⍰ Actions ⍰ Actors
7	Architecture Specification	Definition of the project architecture using UML language Use cases for the actors (humans or animals) identified Use Case and Organization Chart ● block diagram with functions and relations ● behaviour diagram (activity diagram, sequence diagram, state diagram)
8	Principles traceability	Trace between requirement, elements and functions
9	Schedule	Activity Plan
10	Business Plan	● Personnel (man hours), Transport / Transfers, Materials, supplies, tools ● Services, Training, Communication ● Overheads, Contingencies
11	Project Evolution	Fu Evolutions, and receipt of feedback, response to observation, re-design of the system

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Student Coursebook: Volume 3 – Permaculture and the Climate Change Challenge

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Vol. 3 - Permaculture and the Climate Change challenge

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An introduction to **Global Warming** and **Climate Change**

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An introduction to **Global Warming** and **Climate Change**

- **Global warming** as a phenomenon can be understood from an academic perspective as an outcome of the **activity of human beings on earth over thousands of years**.

- The process of which has been dubbed “the **greenhouse effect**”, which causes the temperature on earth to increase. Energy from the sunlight is absorbed typically by earth itself, but this heat is also trapped by greenhouse gases that exist in our atmosphere. Activity on earth such as driving a car emits these greenhouse gases. The trapping of heat creates holes in the ozone layer and allows harmful rays to contact the earth, in turn, heating the globe and causing devastating effects to the earth’s climate. In simple terms, when there are more greenhouse gas molecules to trap the energy from the sunlight, the temperature of the planet increases.

- In the early 19th Century, scientist Joseph Fourier first observed that without this process of the greenhouse effect, the planet would be unliveable.

- The greenhouse effect keeps the planet warm enough for life to survive, however the increase in temperature has become alarming in recent years: according to the October 2018 Climate Change report of the UN Intergovernmental Panel on Climate Change (IPCC), human-induced warming reached numbers likely to be between 0.8°C and 1.2°C in 2017, which have attributed these occurrences to human activities such as burning coal, oil and gas.

- Global net human-caused emissions of carbon dioxide (CO_2) would need to fall by about 45 percent by 2030 to achieve a net zero in 2050 (IPCC Report, October 2018). Global warming has led to a dramatic shift observed in the earth’s climate and weather systems, otherwise known as *climate change*. This includes, and attempts to explain, not only the gradual change in climate observed over thousands of years, but also sudden and catastrophic weather caused by the waxing and waning of climate patterns.

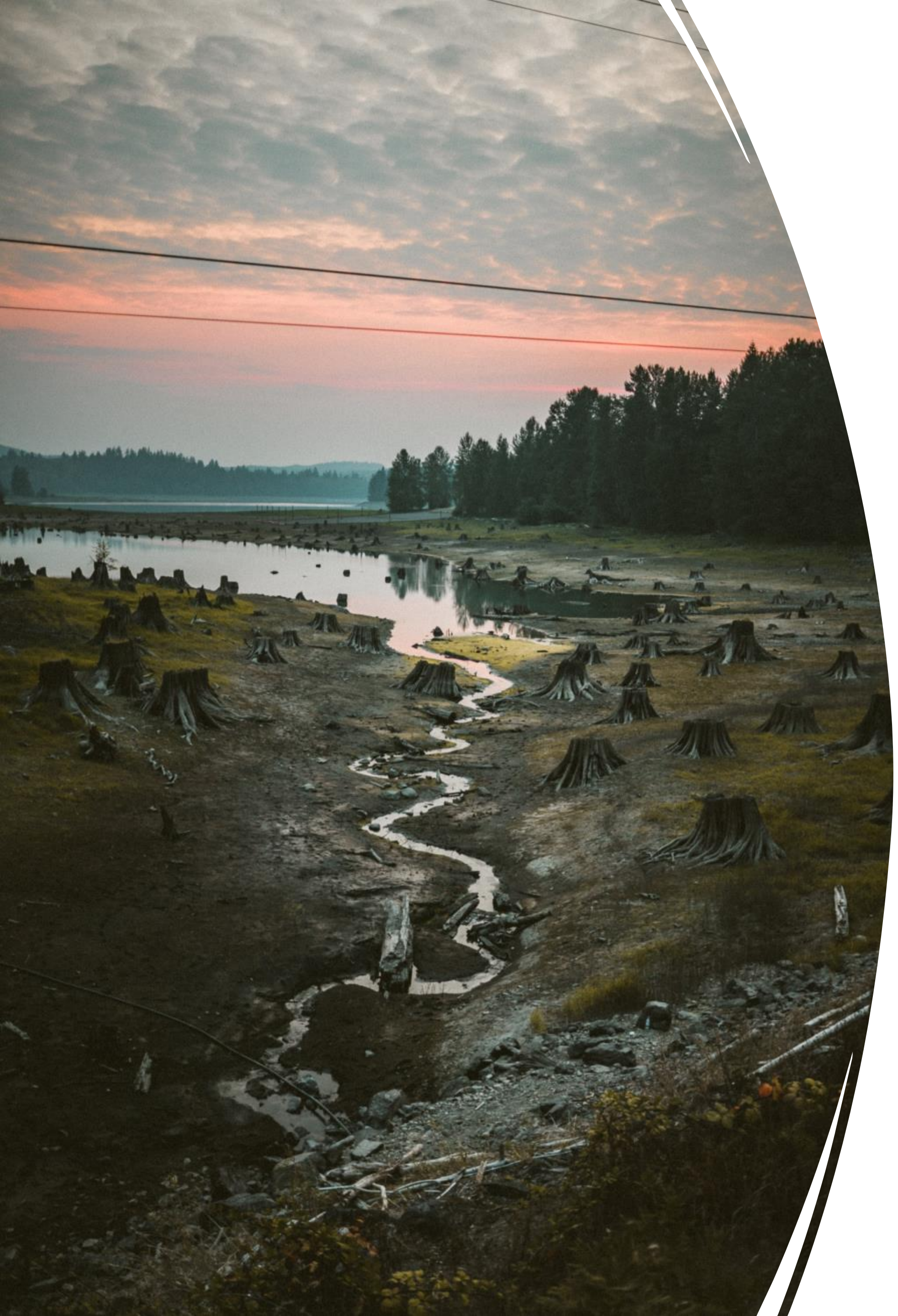
- The phenomenon of climate change also discusses the impact of human activity beyond the burning of fossil fuels. Examples being the release of particles into the atmosphere through the use of aerosols and the effects of deforestation on the climate, which have caused some of the most devastating of contemporary natural disasters.

The **Climate** emergency

Due to the concentration increase in greenhouse gases, the climate has, and is expected to change in drastic and devastating ways. As well as the **rising sea levels** as a result of global warming, **weather is expected to become more extreme** at the hands of human intervention in nature. Expectation from weather performance with the current climate shift include **major storms and more extensive levels of rain** only to be followed by **drier droughts**.

This also posits a **challenge for agriculture**: the changing climate will produce a shift in the foundations of growing crops, animal habitation and water sources. In consequence of both the observation of these changes and The United Nations noting the alarming rate at which the earth is warming, the climate crisis has been dubbed a ‘climate emergency’, calling for the population to reduce their greenhouse gas emission as a matter of urgency.

The United Nations Development Programme (UNDP) notes how every country in the world is being affected significantly as a result of climate related issues, noting both economic and human impacts. 91% of geophysical disasters are in consequence of climate shifts which are causing humanitarian devastations, killing 1.3 million people between 1998 and 2017.



Human intervention in nature

Human intervention on natural phenomena has consequently seen devastating effects.

Human activities such as **industrial agriculture**, farming intensification and deforestation have contributed to the loss of 18% of the Amazonian Rain Forest over the past 40 years. According to the world bank, globally, between 1990 and 2016, the world lost 1.3 million square kilometres of forest.

The **deforestation** that takes place in the forest has knock-on effects to other ecosystems. With no trees to absorb the rainfall, water travels immediately to marine ecosystems, accompanied by minerals and chemicals, whilst causing erosion. In effect, contributing to the ruining of ecosystems and thus, biodiversity and causing land degradation. The process of deforestation has also reduced the number of trees releasing oxygen and absorbing GHGs. At a time when greenhouse gas emissions are more than 50 percent higher than they were in 1990, these careless acts of humankind are having a destructive impact on the environment.

Further, the **burning of fossil fuels** is increasing the temperature of the planet at alarming rates as aforementioned. The global temperature has increased by 0.9°C since the 1990s and according to the IPCC summary for policy makers, this will result in a likely increase in global-mean temperature of about 1°C above the present value by 2025 and 3°C before the end of the next century. This will be more prevalent than the rise in global temperature in the whole of the 20th century. Typically, greenhouse gases that are released into the air by human activity are counteracted and absorbed naturally. This has stabilised the climate.

Human intervention in nature

However, the increasing percentage of carbon dioxide produced by humans has reached almost a third since the industrial revolution and is no longer being absorbed at the rate in which they are emitted. The **rise in greenhouse gases** is worryingly shaping the climate and occurrences that follow. The 'warming influence' humans are having on the planet is resulting in more **grass fires and forest fires**.

2020 saw more than 11 thousand hectares of Australia's bush, forests and parks destroyed in forest fires. In other regions, the warming of the planet has led to the earth's icy areas suffering immensely. Due to this, average global sea level has risen between 10 and 20 centimetres in the past one hundred years, according to the IPCC. due to thermal expansion, melting glaciers and the loss of ice sheets.

Thus, the animals that inhabit the polar regions have decreased, as the climate indirectly makes it harder for them to find food.

In addition, rising sea levels is shifting the climate and causing weather to change unexpectedly causing dangerous hurricanes and typhoons, taking and risking lives and basic human services. Not only is the planet witnessing ruinous effects at the hands of human activity, destroying the earth for both animals and humans themselves, the rise in sea levels and frequency of extreme weathers is adding to **agricultural soil contamination** and posits an **agricultural crisis**.

Permaculture Approaches to mitigate Climate Change

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Contents

The **Anthropocene** defines Earth's most recent geological time period as being huma-influenced, or anthropogenic, based on overwhelming global evidence that atmospheric, geological, hydrological, biospheric and other earth system processes are now altered by humans.

Source: https://theanthropocene.org/

1. Whole Systems Design Thinking

1.1 Context

1.2 Whole Systems Design Approaches

1.3 Whole Systems Design Teams

1.4 Climate Change mitigation and adaptation policies and strategies

1.1 Context

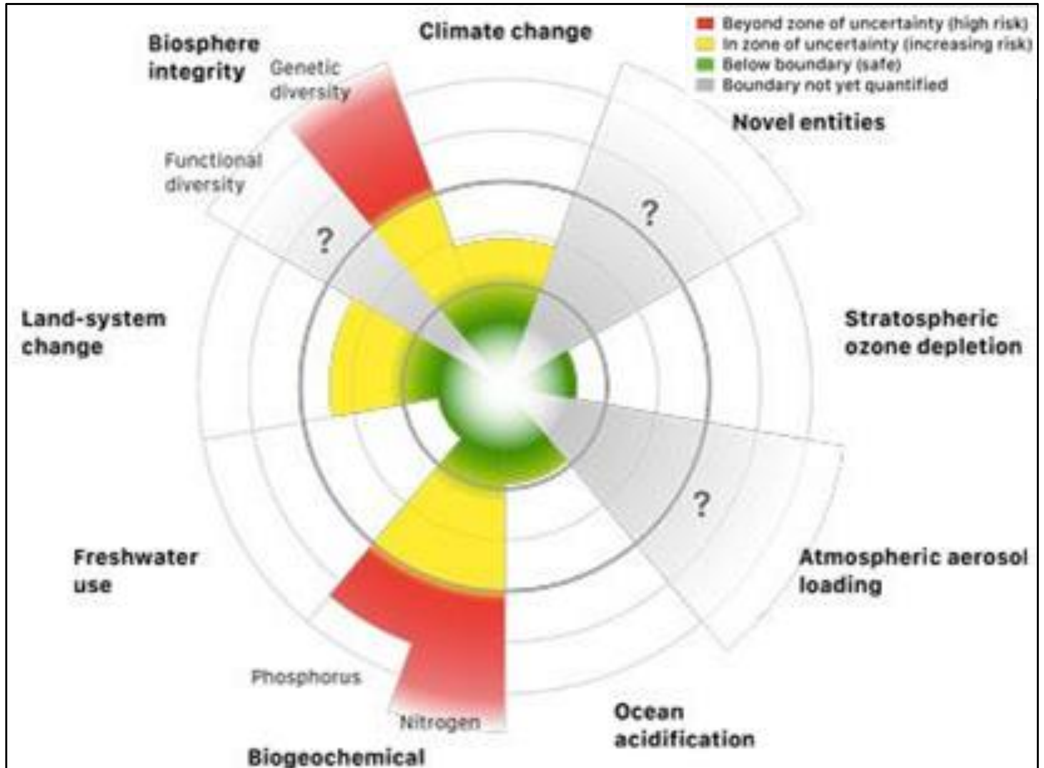
Despite the growing awareness of sustainable development to address the challenges of climate change and related issues, there is still insurmountable evidence that not enough is being done to mitigate these global challenges, as evidenced from Ecological Footprint and Planetary Boundaries data.

Planetary boundaries is a concept about Earth systems and their environmental boundaries, as shown adjacent. This concept was proposed in 2009 by a group of Earth system and environmental scientists led by Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University.

The **Ecological Footprint** is a method promoted by the Global Footprint Network to measure how much nature we have and how much nature we use, from a planetary scale, to nations, to metros, to regions, to towns, to an individual. On a planetary scale, humanity is using the equivalent resources of 1,6 Earths, which is clearly unsustainable.

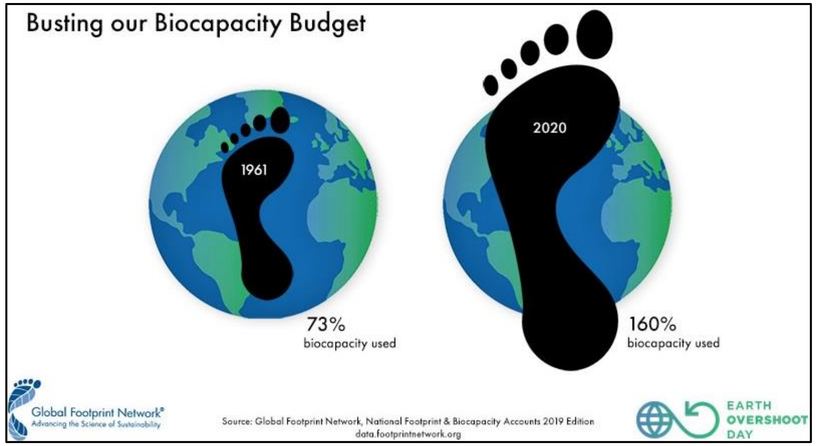
This group defined a framework for a "safe operating space for humanity", as a precondition for sustainable development. The framework is based on scientific evidence that since the Industrial Revolution, human activity has become the main driver of global environmental change.

This framework has nine planetary boundaries, wherein the transgression of one or more boundaries may be detrimental and even catastrophic due to the triggering of non-linear feedback planetary-scale repercussions. By 2020, scientists estimate that four boundaries have already been transgressed, which exacerbates efforts to return to safe operating spaces.



Source: Stockholm Resilience Centre

This is best illustrated by the Earth Overshoot Day, which has shown this day being brought forward almost every year since its inception. For 2020, the overshoot day fell on 22nd August (see image below).



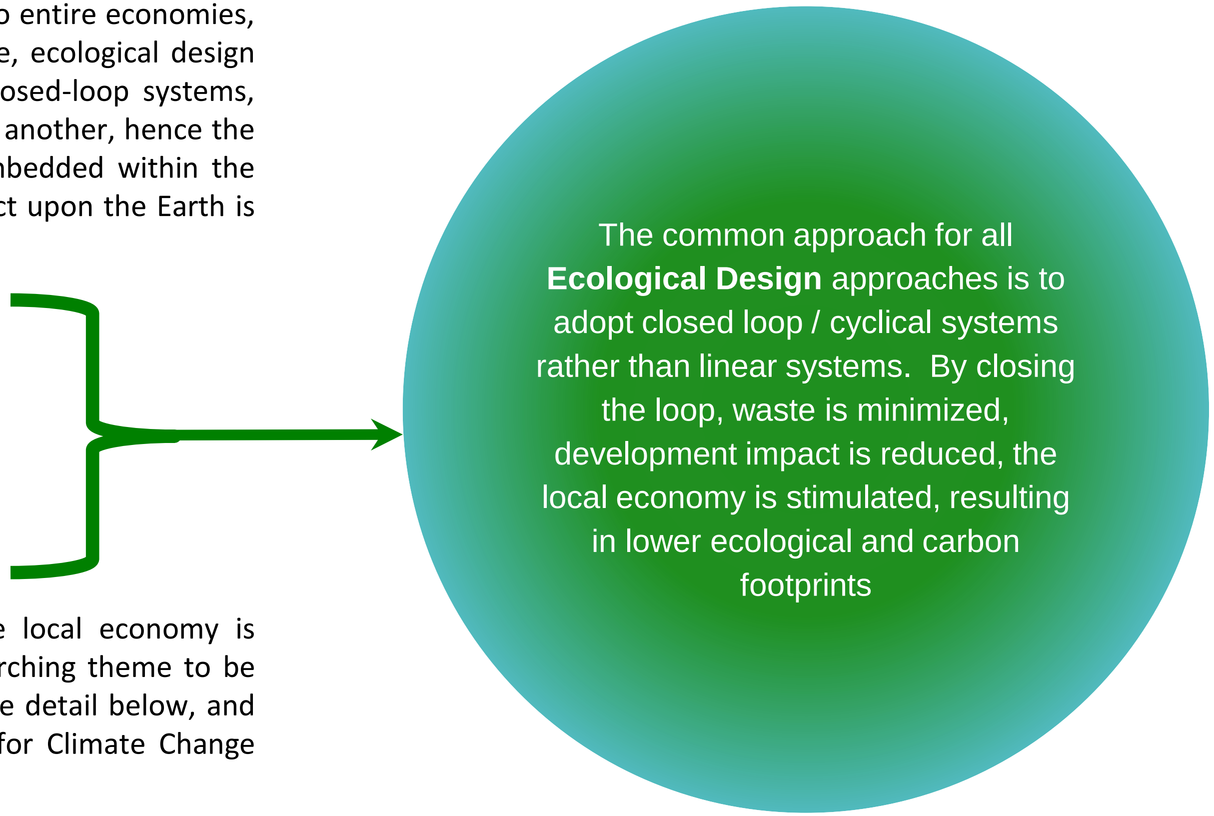
Student Exercise:
What is the Ecological Footprint for your country, and if possible, your region, and briefly discuss your findings.

1.2 Whole Systems Design Approaches

Background

The application of ecological design for sustainability has become a major imperative with increasing understanding of global environmental problems. These problems have been largely created by – extract, use, consume and dispose - linear-type practices, which scale upwards into entire economies, thereby leading to wasteful systems of production and consumption. Meanwhile, ecological design approaches all invoke “whole systems design thinking”, which are circular or closed-loop systems, thereby mimicking Nature wherein the waste of one process becomes the food of another, hence the circular aspect. Thus, a Whole Systems Design Thinking approach has been embedded within the following well known approaches to advance sustainable design so that the impact upon the Earth is reduced:

1. Permaculture - design inspired by ecology
2. Ecological Economics – balancing the four capitals
3. Restorative Environmental Design – importance of place and biophilia
4. Ecological Engineering – nature is the toolbox
5. Industrial Ecology – cyclical vs. linear processes
6. Cradle to Cradle Design – up-cycling and the circular economy
7. Regenerative Design – moving beyond sustainability to regeneration

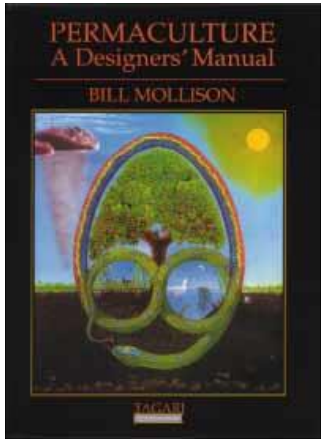


By closing the loop, waste is minimized, development impact is reduced, the local economy is stimulated, resulting in lower ecological and carbon footprints. This is an overarching theme to be applied to mitigate Climate Change. The above approaches are described in more detail below, and then conclude with how these can be used to develop policies and strategies for Climate Change adaptation and mitigation which are aligned with the SDGs.

Permaculture

In the 1970s Bill Mollison and David Holmgren developed Permaculture as a whole systems design philosophy in response to the rapid decline in the state of the Earth's environment, high consumption rates of natural and non-renewable resources and destructive economic systems.

Permaculture is about designing sustainable human settlements. It is a philosophical and practical approach to land use, integrating microclimate, functional plants, animals, soils, water management and human needs into intricately connected, highly productive systems. The idea is one of cooperation with Nature and each other, of caring for the Earth and people and presenting an approach to designing environments that have the diversity, stability and resilience of natural ecosystems, to regenerate damaged land and preserve environments which are still intact. Permaculture is place-sensitive appropriate design based on environmental ethics. It is being used throughout the world to plan buildings, farms, gardens, and villages, and has also been applied in business, industrial, organizational, social and educational planning. Essentially it is common sense design inspired by ecology. What one learns from ecology is how everything is connected to everything else and that life creates conditions where more life can thrive.



Ecological Economics

Ecological design principles also strongly informs the field of Ecological Economics (Costanza, 1989, see short video). The whole systems framework of ecological economics distinguishes four fundamental capitals or resources. In the past "built" capital was increased at the expense of "natural" resources and often our "social" capital, through political activities. From a balanced whole systems perspective we have to optimise the health of the whole system and this means to balance and pay attention to all four types of capital. The intention now is to create sustainable human settlements and wellbeing by increasing or at least not diminishing any of the capitals, while building others. Ecological design at its best is regenerative not just sustainable. It aims to regenerate all vital resources in ways that ideally leave the system as a whole richer, healthier and more abundant. In the design of sustainable communities it is particularly important to pay attention to how proposed designs beneficially affect all four types of capital, namely:

- Built (infrastructure and buildings)
- Natural (environmental)
- Social (quality of interactions)
- Human (skills - education)

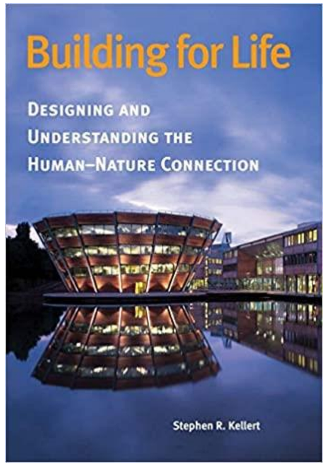
Restorative Environmental Design

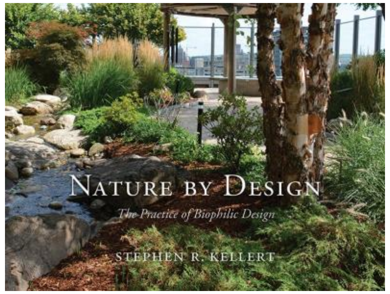
Another important contribution to ecological whole systems design was developed by Professor Stephen Kellert of Yale University - see a short video (3 minutes), "Biophilic Design: The Architecture of Life". Human and natural systems are connected, linking 'quality of life' and integrity of natural systems. Ecological and human values are mediated through landscape, providing economic, social and psychological as well as environmental advantages. The built environment and its operation uses large amounts of resources and so Restorative Environmental Design emphasises that wise design decisions have to take into account:

i. How the minimise their impact on ecosystems services and in doing so minimise their ecologcial footprint and carbon footprint; and,
ii. How design can be an expression of our interconnection with and innate love for nature (biophilia); and how local traditions, indigenous wisdom, and vernacular architecture are all valuable expressions of the 'spirit of place' in a given location and can inform restorative design.

To summarise, Restorative Environmental Design can be encapsulated as:

- Ecosystem services: Low impact design = Small ecological footprint.
- Biophilia: Organic design using natural materials and ecological engineering.
- Spirit of place: Vernacular design with a strong relationship to place.



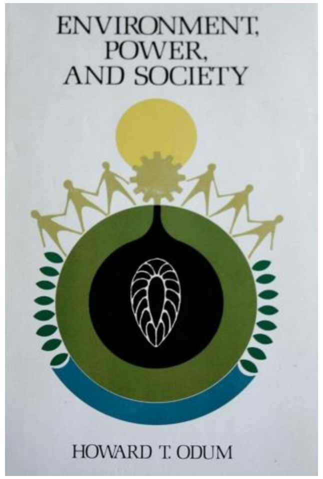


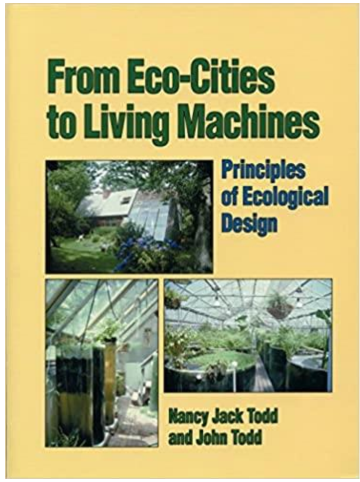
Ecological Engineering

The basic principles in the field of ecological engineering were first put forward by Howard T. Odum in his book Environment, Power and Society over thirty-five years ago. The fundamental idea is that, in addition to modelling human designed systems on Nature, we can use complete ecologies to carry out useful tasks.

Living technologies are different from dead technologies in that the main working parts are alive. This means they are not really "parts" at all, but participants in a continuously transforming web of living relationships and processes. Such living systems self-replicate, auto-regulate, and form adaptive networks within networks at different scales. One can work with these complex adaptive systems to support them in their regenerative functions. Different ecologies can be linked to handle many inputs, self-manage a multitude of internal, closed-loop functions and provide a variety of outputs.

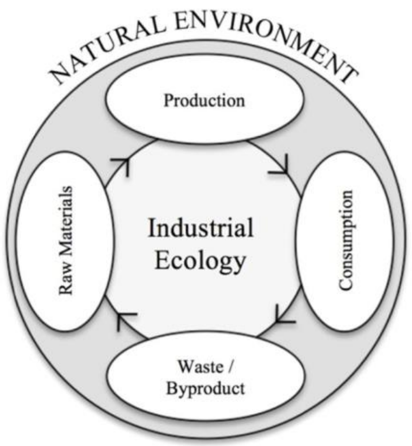
While the language is still mechanistic, what Odum was referring to here is that if we design with nature we can restore and regenerate ecosystems services. John Todd describes ecological design as the science of following nature's operating instructions and the art of creating elegant solutions adapted to the uniqueness of place.





Industrial Ecology

Nature is seen as both mother and teacher, so the basic idea is that our industrial and development processes can be modelled on natural ecosystems. This is the field of ecological design and engineerir and industrial ecology. This goes beyond the typic industrial production and consumption models, whic are linear and mechanistic, to closed loop system which are similar to natural ecosystems. Therefor an industrial plant or a new town or an ecovillage designed as a living system, which is an integral pa of the larger bioregion it is nested in. The inputs ar outputs of the human engineered facilities are see as typical of natural ecological sub-systems and th wilderness is taken as the greater whole in the desig process.



At present, our industrial processes emphasise the moving of materials and energy from Nature through the economic system as the primary way we "create value". The main economic activities are, therefore, producing and consuming. By contrast, in natural systems, the processes of production and consumption, including recycling of wastes and nutrients, are balanced processes. The system balance and stability is only disturbed when we extract too many resources and/or waste streams become overloaded with pollutants.

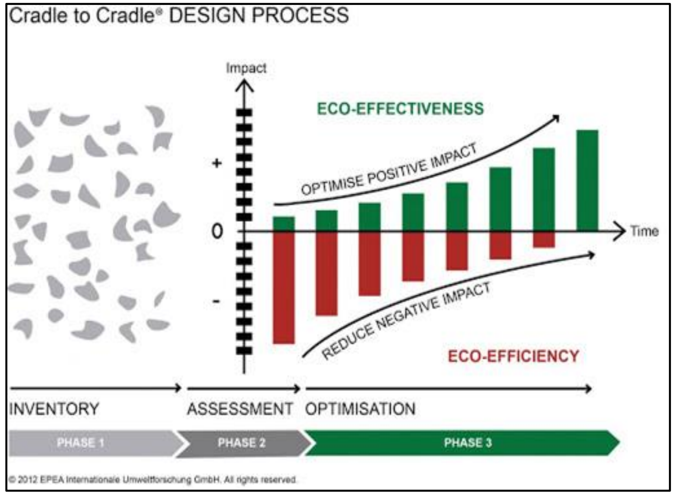
If industrial processes can have these same attributes, they will be highly effective and often restorative. A paradigm change happens as one begins to think about industry as part of, and not separate, from Nature, that is human, economic and industrial activities are living systems participating in the Earth's natural systems.

Cradle to Cradle (C2C)

One successful way of taking the concepts of ecological design and industrial ecology into the heart of many industries has been the Cradle to Cradle (C2C) framework of improvement promoted by William McDonough and Michael Braungart. They contributed a very useful distinction between technical and biological metabolism (see image below). All material flows should remain within one of these two cycles. That is the basis for creating circular economies.

To achieve this shift towards integrated, cyclical whole-systems design one needs to transform products, and how these are designed and produced, in ways that allow disused products at the end of their useful life to be disassembled into fully recyclable or up-cyclable industrial feedstock or organic feedstock. Simply to recycle is not enough, if it only leads to a material finding another use in a less valuable and less complex product before ultimately ending in a landfill or as waste.

Up-cycling is about maintaining biological and industrial nutrients (resources) cycling through the biological and industrial metabolisms of our industrial processes so that they can be converted into higher quality or equal quality products at the end of a product's useful life. See this short video (2 mins) for more information.



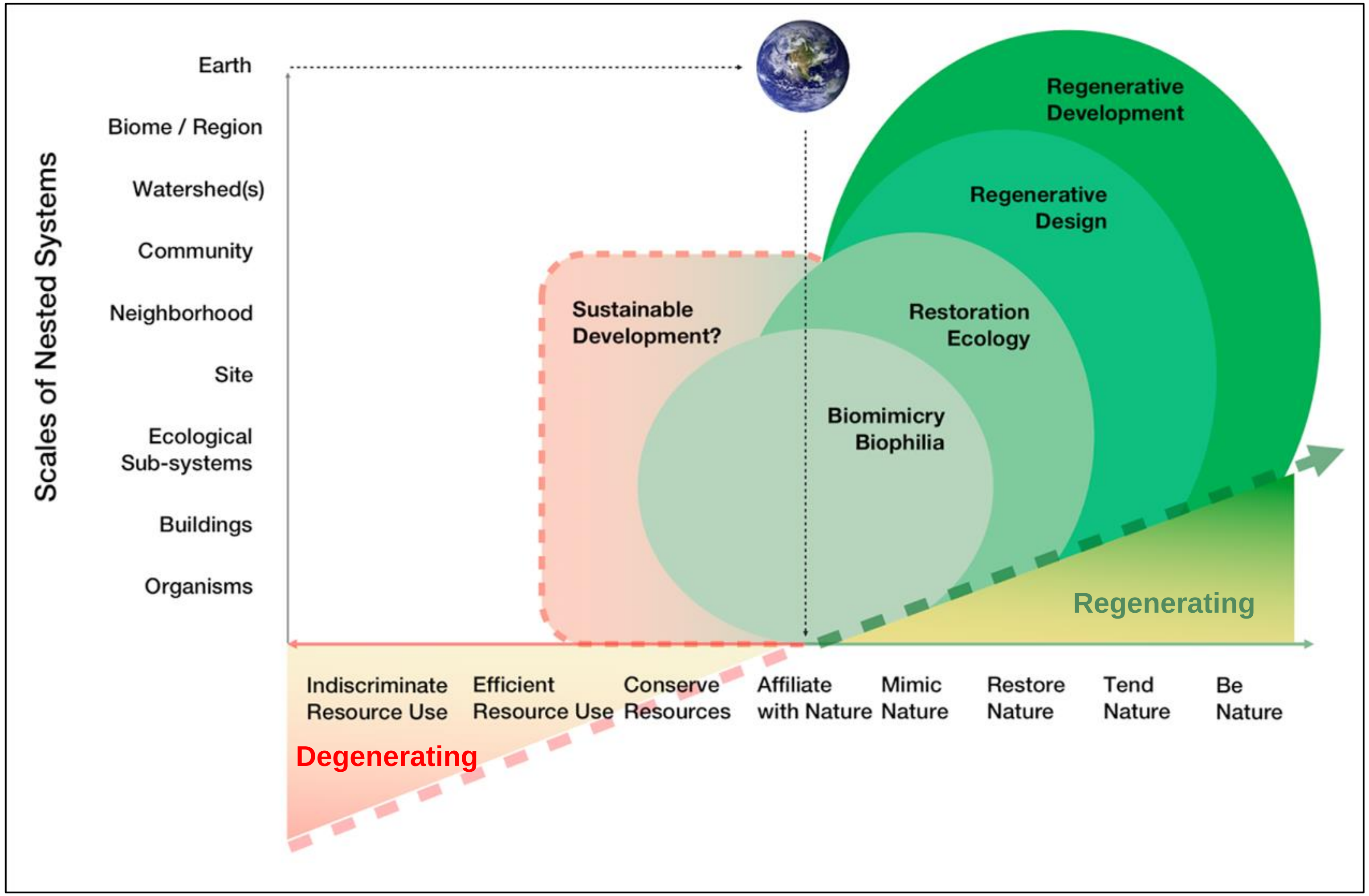
Source: Dr. Michael Braungart

Regenerative Design

Bill Reed has mapped out some of the essential shifts that will be needed to create truly regenerative cultures. In 'Shifting our Mental Models', a framework is laid out that puts different approaches to ecological design into a relationship with regard to the extent that they aim for truly regenerative solutions. Reed named 'whole-systems thinking' and 'living-systems thinking' as the foundations of the shift in mental model that we need to create a regenerative culture. As Reed puts it: "Sustainability is a progression towards a functional awareness that all things are connected; that the systems of commerce, building, society, geology, and nature are really one system of integrated relationships; that these systems are co-participants in the evolution of life" (2007). When one makes this shift in perspective one can understand life as "a whole process of continuous evolution towards richer, more diverse, and mutually beneficial relationships". Regenerative Design is often viewed as the pinnacle of Whole Systems Design Thinking approaches as shown in the adjacent figure and outlined in the following sequence of resource usage: Degenerative to Sustainable to Regenerative. In other words, Regenerative Design moves beyond just sustainability since it regenerates natural capital.

Student Exercise:
Explore your neighbourhood or town / city and identify an activity that is, (1) linear and (2) cyclical.
Outline how the above linear activity can become more sustainable through a cyclical approach.

Design approaches towards Regenerative Design



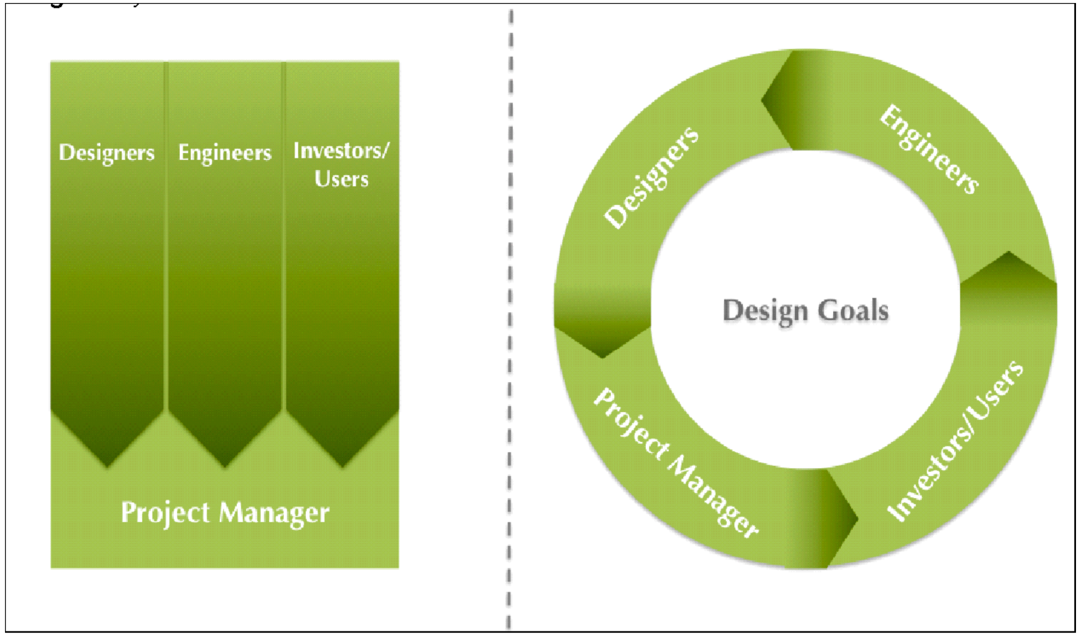
Source: www.regenesisgroup.com

1.3 Whole Systems Design Teams

Design Collaboration

Whole Systems Thinking and Ecological Design are central elements of the transition to sustainable and regenerative communities, cities and bioregions. It requires Design Collaboration within trans-disciplinary teams of different experts and future users, compared to the dominant conventional silo mentality, as illustrated in the figure below. All stakeholders ought to embrace design collaboration in the way that engagements are made in order to establish a fertile environment for co-creativity to flourish which ought to bring about the best from member contributions, failing which, team members may be stifled and intimidated to bring out their best and simply comply with the bare minimum.

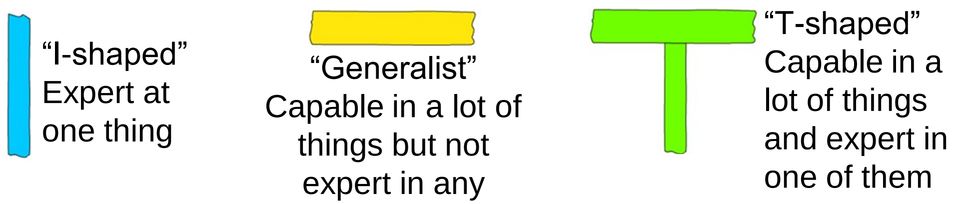
Design Team Approaches



T-shaped skills in a project team

Having a collaborative design team does not simply imply that an integrated and wholistic design will evolve since there will still be challenges among the skills set of the team members. Generally, one will find team members who are either specialists or generalists, and seldom both. For example, an engineer will most likely provide specialist input towards the design of a wastewater treatment system, whilst a project manager, who has generalist skills, will co-ordinate the integration of the engineering design within the project plan.

The term “T-shaped skills” helps to differentiate between generalists and specialists. Herein, the vertical bar on the letter “T” represents the depth of related skills and expertise in a single field – a specialist. Whereas, the horizontal bar on the letter “T” represents the ability to collaborate across disciplines with experts in other areas and to integrate areas of expertise – a generalist, such as, project managers, focalisers and weavers. An ability to recognize T-shaped skills within a team and to co-ordinate and integrate collective input is highly dependent on a collaborative team environment where creativity is allowed to flourish. Individuals with T-shaped skills, that is, both generalist and specialist skills, are highly sought after and can be a great asset to any team.



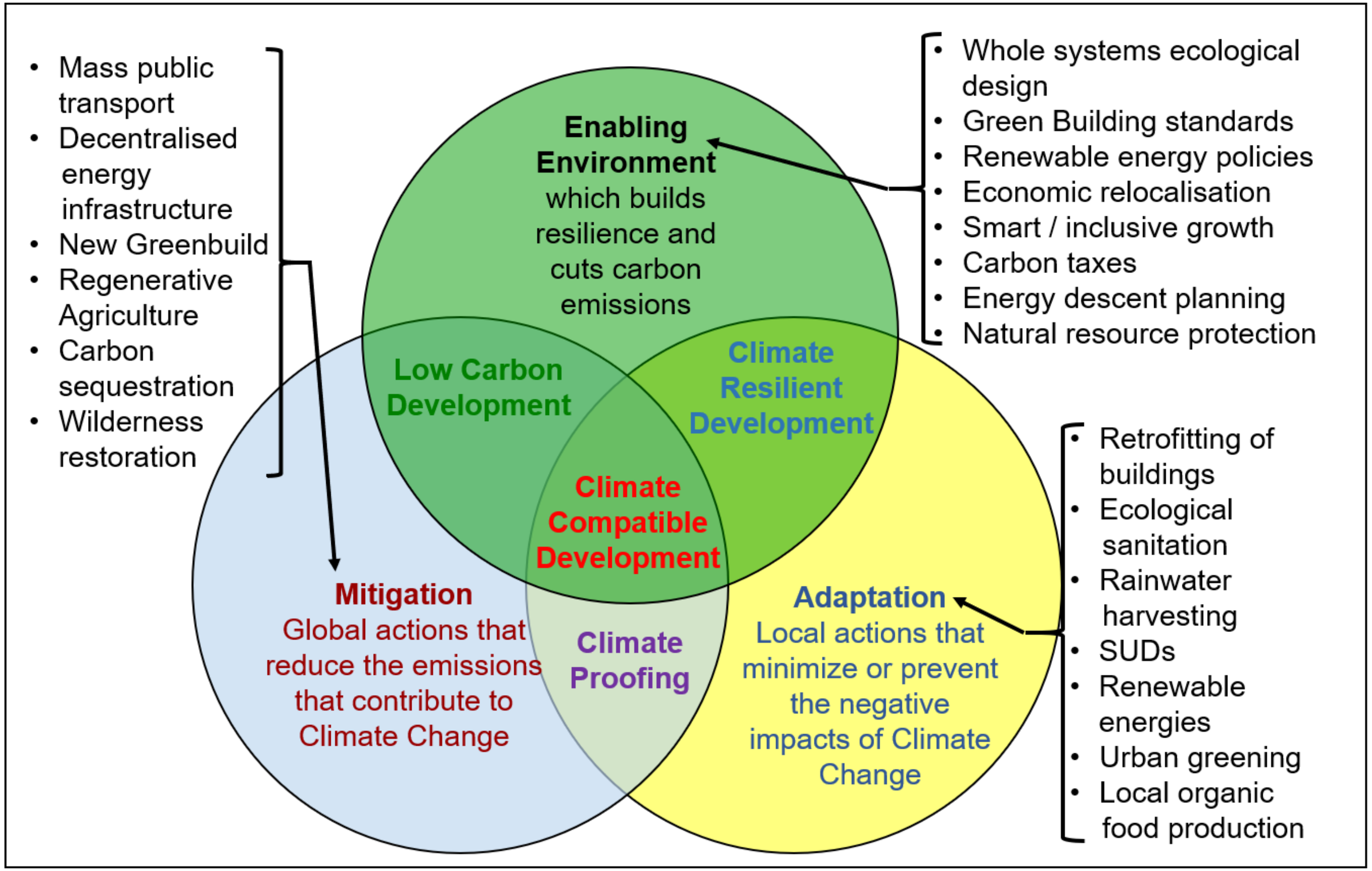
Student Exercise:
Is your foundation study field setting you up as an Expert, a Generalist, or both (“T-shaped”)?
Explain what skills set you wish to attain to advance your career.

1.4 Climate Change mitigation and adaptation policies and strategies

Whole Systems Thinking approaches towards sustainable design should be used to develop policies and strategies for Climate Change adaptation and mitigation that are aligned with the SDGs. To this end, a positive enabling environment is required with appropriate policies for sustainable development, which in turn, facilitates the development of appropriate strategies for Climate Change adaptation and mitigation for all economic sectors, as depicted in the adjacent figure. Generally, climate mitigating actions have a global impact whilst climate adaptation actions have a local impact. Herein, the policies and strategies should focus on the categories of human impact, notably, the built environment, utilities, transport, energy and food production.

Student Exercise:
Explore your neighbourhood or town / city and describe at least one activity in each of the three interrelated components that is being done, and another which ought to be urgently considered.

Climate Change mitigation and adaptation policies / strategies



2. Permaculture solutions for Agriculture to mitigate to Climate Change

2.1 Context

This section explores some Permaculture-inspired solutions to mitigate Climate Change for the Agricultural sector. These solutions also stem from Yeomans Scale of Permanence, also referred to as the Keyline System, and later refined by Regrarians, which design sequence is included within the Permaculture design principles. The following regenerative design approaches explained in this section are categorised into "***design systems***" and "***design components***", in accordance with their application. Thereafter, these solutions are broadly ***integrated*** in order to highlight how these regenerative approaches enhance biodiversity and carbon sequestration, thereby providing important ecosystem services that establishes resilience to mitigate the challenges of climate change. If these regenerative approaches are adopted wholescale, then agriculture can make a significant contribution to offset climate change, completely. See these short videos for further information: Video 1, Video 2 and Video 3.

- Climate Change solutions for application of ***Design Systems***:
  - Land restoration through rehabilitation of riparian zones
  - Landscape-based rainwater harvesting
  - AgroForestry
  - Limited Till with Yeomans Keyline Plow

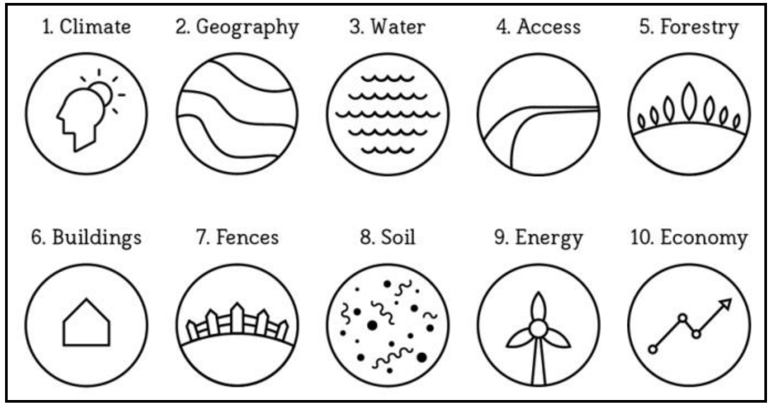
- Climate Change solutions for application of ***Design Components***:
  - Mycorestoration
  - Vetiver Systems
  - Biochar
  - Seedballs

- ***Integrated*** Climate Change solutions:
  - Species Diversity and Ecosystems Functions
  - Drought-, flood- and fire-proofing landscapes
  - Soil carbon sequestration
  - Ecosystem Restoration

Evolution of the Scale of Permanence

Keyline Scale of Permanence *Yeomans 1958*	**Regrarians ® Platform** *Darren J. Doherty*
1. Climate	1. Climate
2. Land Shape	2. Geography
3. Water Supply	3. Water
4. Farm Roads	4. Access
5. Trees	5. Forestry
6. Permanent Buildings	6. Buildings
7. SubDivision Fences	7. Fences
8. Soils	8. Soils
	9. Economy
	10. Energy

Source: www.permacultureapprentice.com



Source: Regrarians,

2.2 Climate Change solutions for application of Design Systems

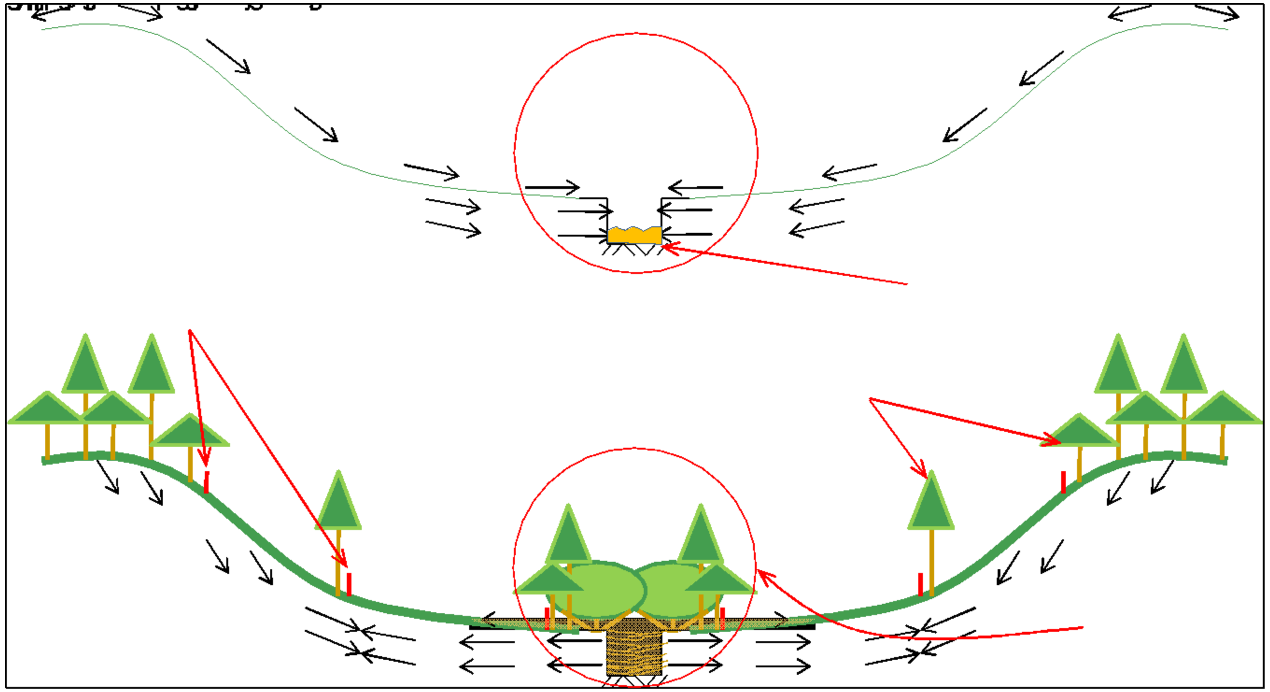
Land restoration through rehabilitation of riparian zones

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 top soil 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 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 shown in the adjacent photo and figure. 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.

See these short videos for further information: Video 1, Video 2 and Video 3.

The process of rehabilitating a riparian zone with eroded gullies



Source: Regrarians, with edits by E. Gori

Source: Researchgate

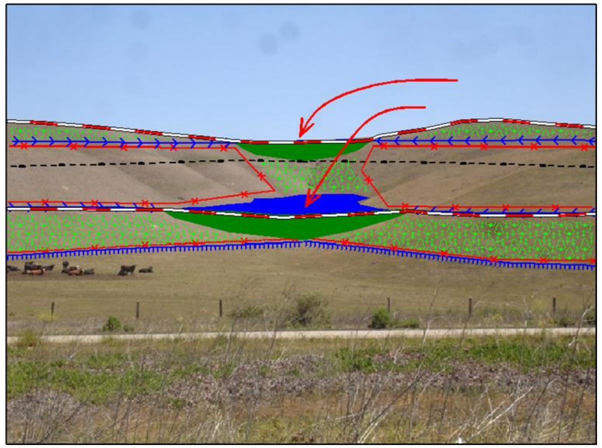
Student Exercise:
Identify an eroded water course with a limited or non-existent riparian zone in your neighbourhood and show on a map.
Annotate the appropriate restoration process for this water course and riparian zone on a map.

Landscape-based rainwater harvesting

One of the most important design components to mitigate Climate Change is to design for landscape-based rainwater harvesting in order to slow down, spread, and sink rainwater, thereby retaining moisture in the landscape and recharging the aquifers. Herein the Keyline System from Yeomans Scale of Permanence shows great promise for designing landscapes which can harvest their entire water supply needs from the inherent characteristics of the land formation, also 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 the adjacent figure, 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.

PA Yeomans developed the Keyline System on his farm, Yobarnie (adjacent photo and short video), 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. See these short videos for further information: Video 1, Video 2 and Video 3.

An example of Keyline System design for water



Yeomans' farm, Yobarnie, Australia

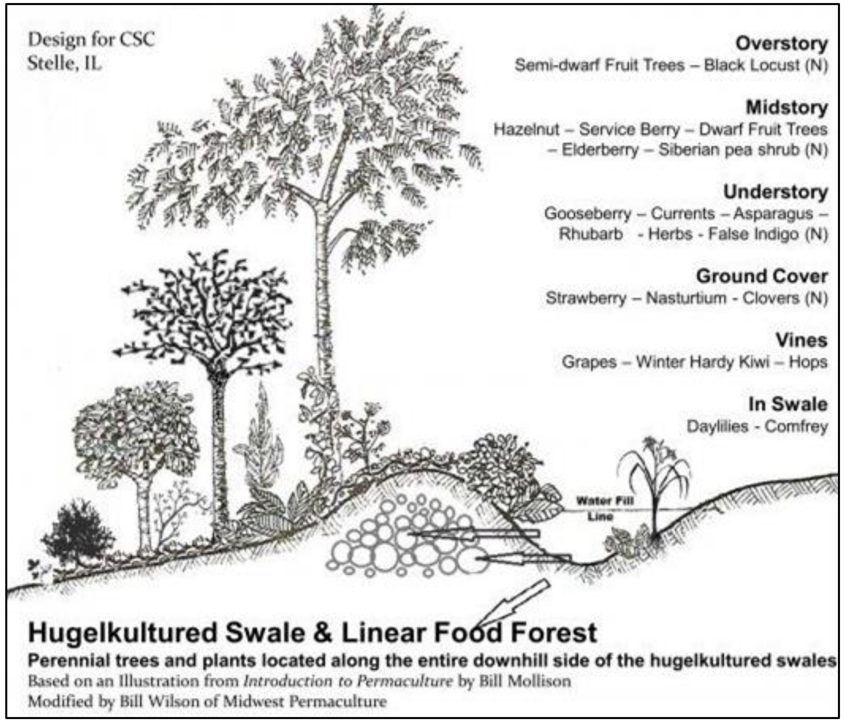
Student Exercise: Practice setting out swales on contour with an A-Frame and a Water Level. Practice desktop Keyline design for a rainwater harvesting plan from an orthophoto.

Agroforestry

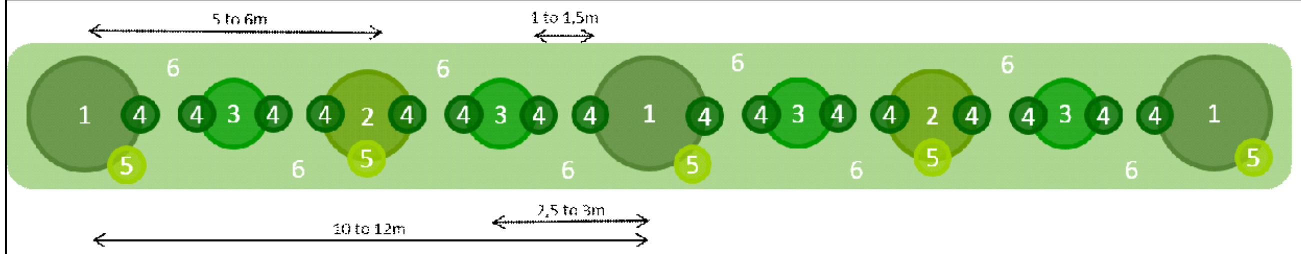
According to the FAO, agroforestry is collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. This can take the form of a fully-fledged food forest or individual species. As such, Agroforestry brings about a greater degree of biodiversity and biomass, which acts to sequester and store carbon, besides enhancing the hydrological cycle, which in turn, will both increase rainfall and also moderate its distribution. See these short videos for further information: Video 1, Video 2 and Video 3.

Two examples are provided of a forest shelter-belt, namely, a cross-section for a temperate climate forest-belt, and a plan of a forest-belt which correlates with a classification of "Cfa" for a Humid sub-tropical climate, according to the Köppen–Geiger climate classification system.

Cross-section example of a temperate climate a forest-belt



Plan example of a sub-tropical planting plan for a forest-belt



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.

Source: E. Gori

Student Exercise: Identify the Köppen–Geiger climate classification system for your region. Plan a typical forest-belt for your region using the template examples provided.

Limited Till with Yeomans Keyline Plow

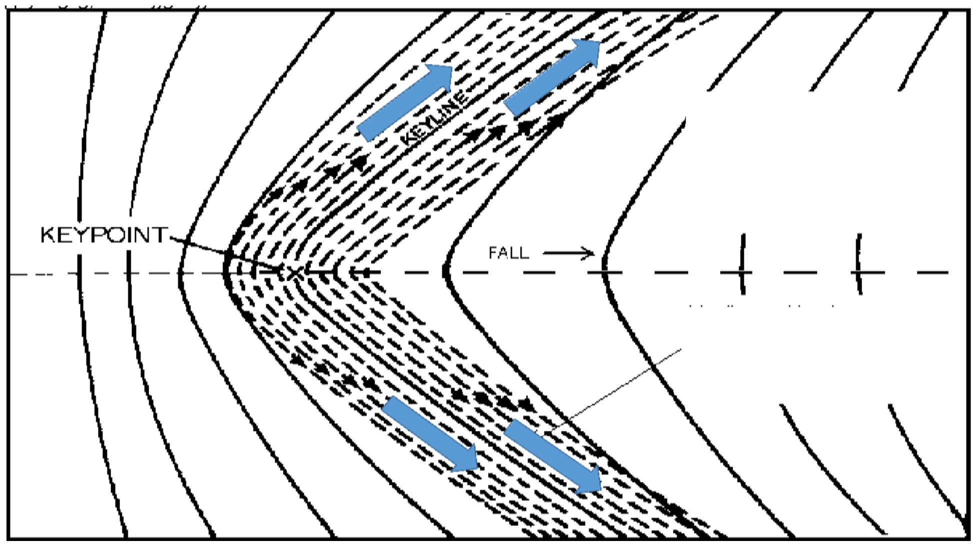
Besides Yeomans Scale of Permanence or the Keyline System, PA Yeomans also developed a limited till plow which he called Yeomans Keyline Plow as shown in the adjacent photos. This type of Keyline plow has been successfully used to rehabilitate arid farmland which has lost its soil fertility through too much tillage. For this reason, the Keyline plow 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

Keyline swales play a important role in determining the pathways of Keyline plowing. Plowing parallel to Keyline swales, the shanks of the Keyline plow drills the soil open to allow water seepage and aeration, whilst simultaneously draining water across the contours from valleys where soil moisture is abundant, to ridges where soil moisture is lacking as illustrated in the adjacent figure. See these short videos for further information: Video 1 and Video 2.

Yeomans Keyline Plow with shank pot seeders

Illustration of Keyline cultivation

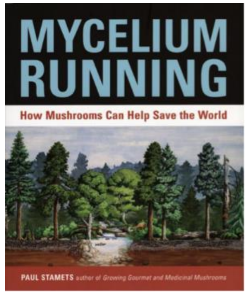


Student Exercise:
Identify the dominant use of farm equipment for land preparation in your region (eg. ploughing, harrowing, levelling).
Interview a farmer or two and ask them to explain their methodology for land preparation and ask them if they have considered any more sustainable methodologies, such as Limited-Till.

2.3 Climate Change solutions for application of Design Components

Mycorestoration

The importance of mycelium in soils cannot be overstressed. It is the mycelium which connects to plant roots in order to enhance the symbiotic relationship between plants and soil, wherein soil minerals and nutrients are exchanged. Further, it is the mycelium which enhances soil structure and moisture retention. Therefore, introducing mycelium in depleted soils will promote soil restoration, which in turn, supports plant growth and an increasing biomass and biodiversity.



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. Here is a link to a TED-talk (17:40mins) by Stamets that is well worth watching if you are unfamiliar with this field and his work. The four components of mycorestoration include:

i. Mycofiltration: the filtration of biological and chemical pathogens as well as controlling erosion.
ii. Mycoforestry 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 ecosystems regeneration becomes a central activity for humanity in the 21st Century. A parting quote from 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."*

Comparison of two Douglas fir trees, one with and one without introduced mycorrhizae.

The polluted / waste water in this channel can be significantly alleviated by inserting a myceliated straw bale to interface with the water flow.

Student Exercise:
Find a sample of mycelium rich rotting wood or soil in a nearby forest.
Research a methodology for enhancing mycelium into an orchard or agroforestry plot.

Vetiver Grass Systems

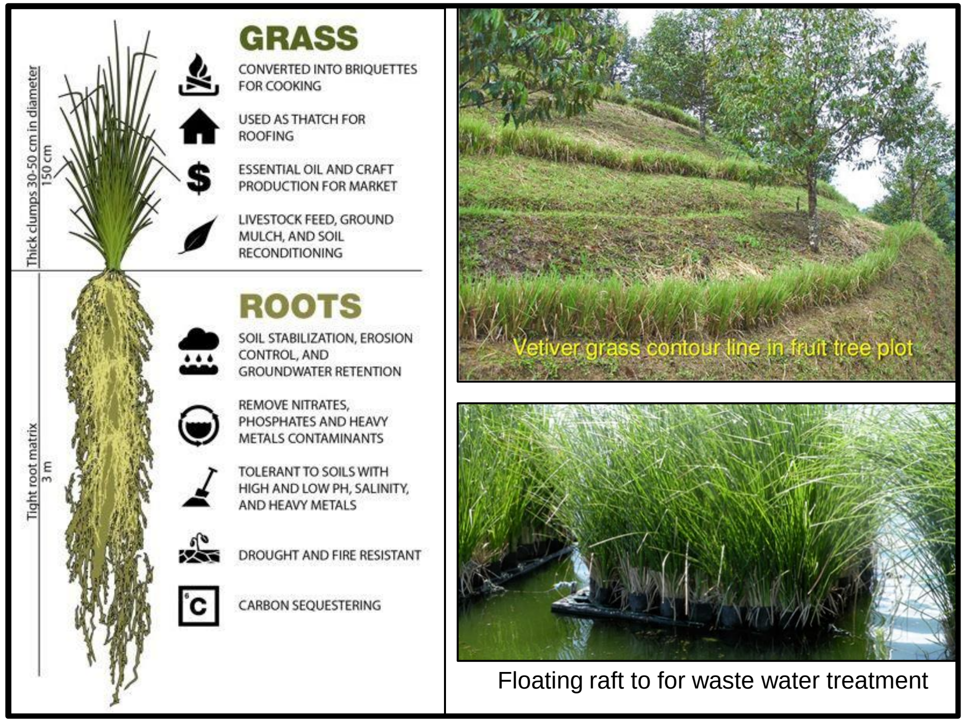
Vetiver grass, *Chrysopogon zizanioides*, is a unique grass with a long hairy root that anchors the soil and is planted on swales to mitigate soil erosion. Vetiver grass is not an invasive plant and is found in the tropics and subtropical areas, although it also grows fairly well in temperate zones. 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.

View this short 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 projects.

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

Vetiver Grass Systems



Floating raft to for waste water treatment

Source: *www.vetivergrassuk.com*

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

In addition Vetiver grass leaves and roots can be used:

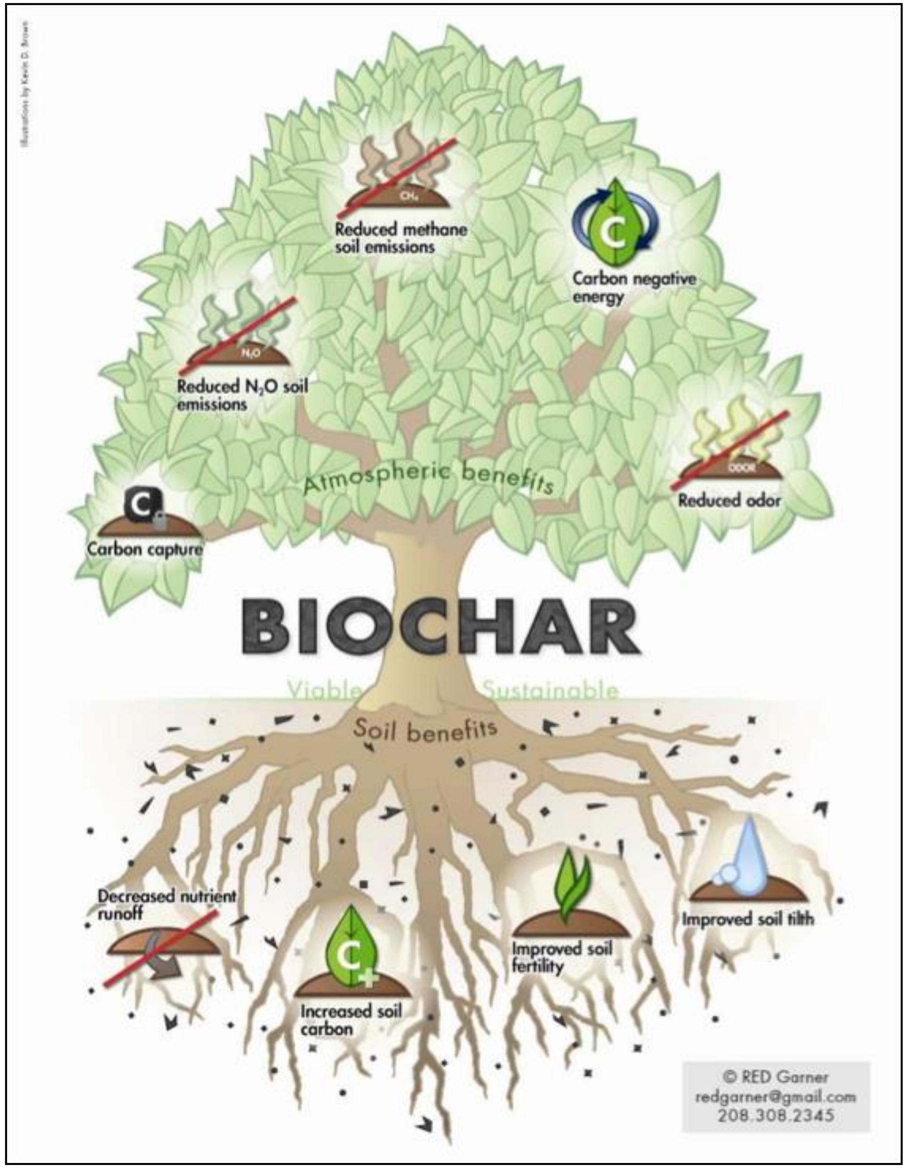
- As a source of feed for livestock and wild life
- For pest control (intercropping, bio-pesticide)
- For handicraft (baskets, hats)
- In building construction (bricks, roofing)
- For water purification and medicinal purposes
- As an ingredient for cosmetics

Soil enhancements

Biochar is one of the techniques that scores highest for its greenhouse gas abatement rate (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".

Biochar 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).

The benefits of Biochar (source)



Fulvic acid is found in soil and plants, where it carries out two indispensable functions: to absorb from soil minerals and trace elements and all nutritional and remedial components left there by microbial action, and to transfer this valuable content into plants cells, where it is metabolised and used for healthy growth. When plants die and eventually decompose, they return their mineral, nutritional and remedial value, fulvic acid including, back to soil and the cycle repeats itself again.

Fulvic acid is an organic material created over a long passage of time by the action of microbes breaking down dead and dying vegetable matter. Thus, it is largely found in pre-historic deposits of lignite, a soft, brown coal, that has developed from peat through bacterial action and pressure and heat over millions of years. Smaller quantities of fulvic acid are also found naturally in soil. From ancient remains we know that plant life flourished in an environment abundant with fulvic acid and it seems that most of plants and food crops of today must contain at least some of those riches, but in reality few do.

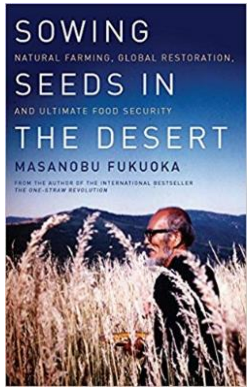
Today, our soils provide less and less natural nutrition, especially minerals, to the plants and food crops, due to prolonged poor agricultural practices, such as excessive use of chemical fertilisers, insecticides, pesticides, and herbicides, and the resulting erosion and mineral depletion. Market forces are driving many farmers to produce ever increasing volumes of food critically lacking in organic trace elements and other nutrients, but full of chemical residues. In turn, we are deprived of adequate natural supplies, including fulvic acid, in quantities that Nature intended for us to have, which would otherwise be available to us through plants we eat *(Source: Fulvic Force)*.

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 short video (5 mins).

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 short video (2 mins) from Dronecoria: Open Source Restoration.



Seedballs, source, Seedballs Kenya

Student Exercise:
Make a list of ingredients for a small bowl size mix of seedballs infused with flower seeds designed to attract pollinators to a vegetable garden.
Make the seedballs, allow to dry, retain a few in a sample pot, disperse the rest, and monitor progress in the sample and the garden where dispersed.

2.4 Integrated Climate Change solutions

Species Diversity and Ecosystems Functions

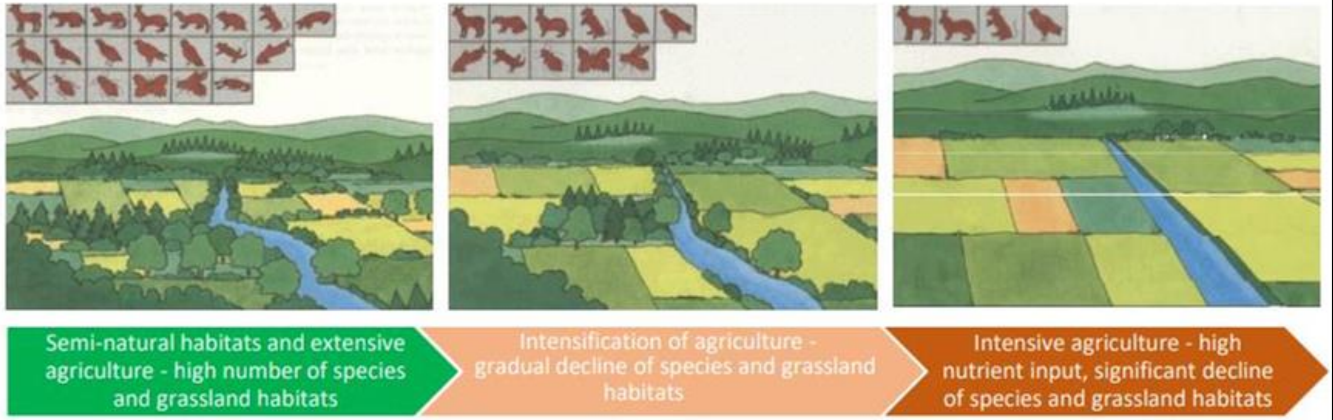
The IPBES Global Assessment Report published in May 2019 for the UN Convention on Biological Diversity puts habitat loss as the number one direct driver of the loss of biodiversity and species extinctions with agriculture and urbanisation mentioned as the primary drivers. The report specifically states that climate change is not a direct driver of habitat loss but exacerbates existing drivers.

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 below.

Global trade in foodstuffs is equally a driver of degradation and carbon emissions. 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. Eliminating poverty, hunger and inequality are evidently achievable through a transition to local, regenerative agricultural practices. 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.

Changes in biodiversity due to intensification of farmland usage



Source: ECA, based on *Landesanstalt für Umweltschutz Baden-Württemberg, Landschaft natürlich* (1992).

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. Swales manage to slow, spread and sink rainwater, whilst also creating a water plume in the soil downslope from the swale. This water plume supports 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 the adjacent figure, 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 CO_2 that mitigates against Climate Change.

Within the shelter-belt micro-climate zones, raised bed cultivation is a complimentary approach for draining excess rainwater, whilst maintaining a mound for optimum root growth, maximum aeration, infiltration and drainage, as shown in the adjacent sketches. Raised beds also reduces soil compaction and only requires smaller and lighter farm machinery. See short video on raised beds.

Integration of swales and forest belts

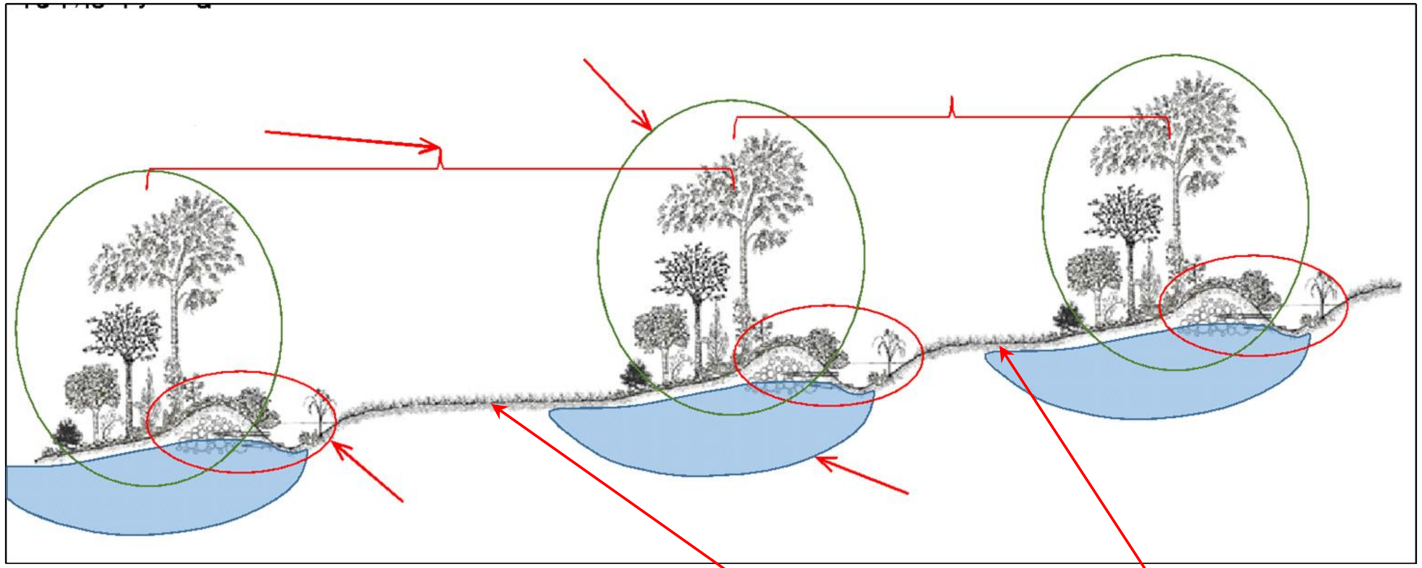
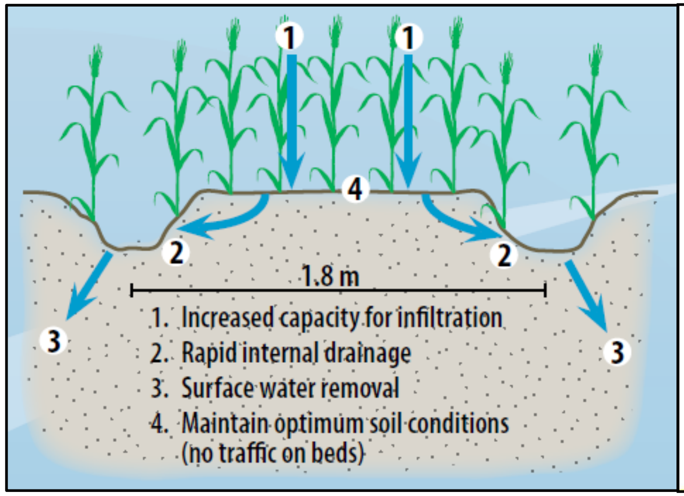
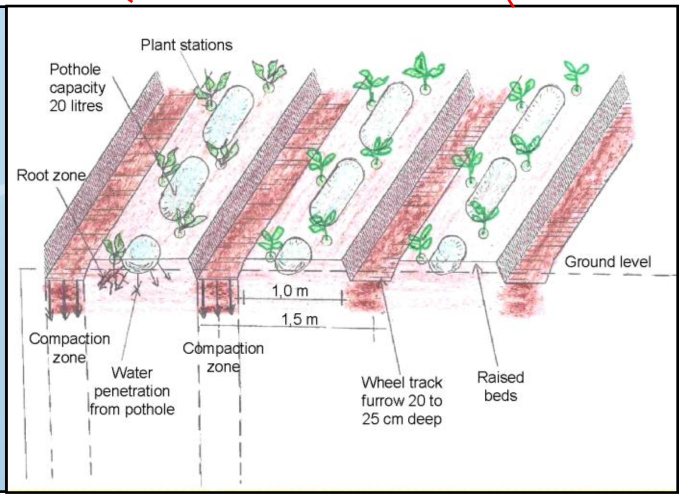


Illustration of raised beds



Source: Soil Quality



Source: Permaculture2012

The potential of carbon sequestration to mitigate Climate Change

It suffices to state the importance of healthy 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 can 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).

Fig. In this paired site comparison, parent material, slope, aspect, rainfall and farming enterprise are the same. Levels of soil carbon in both paddocks were originally the same.

LHS: 0-50cm soil profile from a paddock in which groundcover has been actively managed (cropped and grazed) to enhance photosynthetic capacity.

RHS: 0-50cm soil profile from a conventionally managed neighbouring paddock (10 metres through the fence) that has been set-stocked and has a long history of phosphate application.

NOTES:

i) The carbon levels in the **0-10cm increment** are very similar. This surface carbon results from the decomposition of organic matter (leaves, roots, manure etc), forming short-chain **unstable 'labile'** carbon.

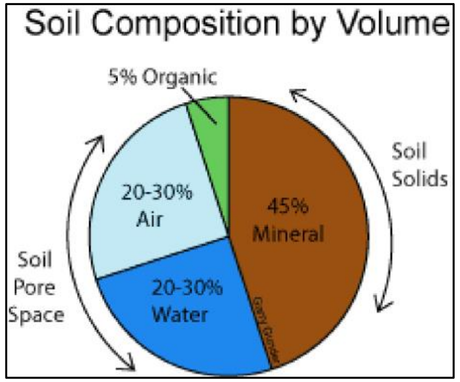
ii) The carbon **below 30cm** in the **LHS** profile has been sequestered via the **liquid carbon pathway** and rapidly incorporated into the humic (**non-labile**) soil fraction. Long-chain, non-labile carbon is highly STABLE.

Photo: Christine Jones
Property: 'Winona', operated by Colin and Nick Seis

The World Bank report on Carbon Sequestration in Agricultural Soils 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".

At this point, it is worth noting the typical composition of undisturbed soil in nature (see adjacent figure) 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 rips 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.

Soil composition by volume



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 (see adjacent table) 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 sequestrated.

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 CO_2 in the atmosphere from the current 413 ppm within a few years. Dr. Elaine Ingham has made similar estimates in the short 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.

It can therefore be argued that farmers of the world have the potential to almost single-handedly sequester the earth's entire CO_2 emissions by reverting to an acceptable CO_2 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 CO_2 emissions, is this not then the investment game changer to drive Regenerative Agriculture? See these short videos for further information: Video 1 and Video 2.

Quantifying the benefits of humus in the soil

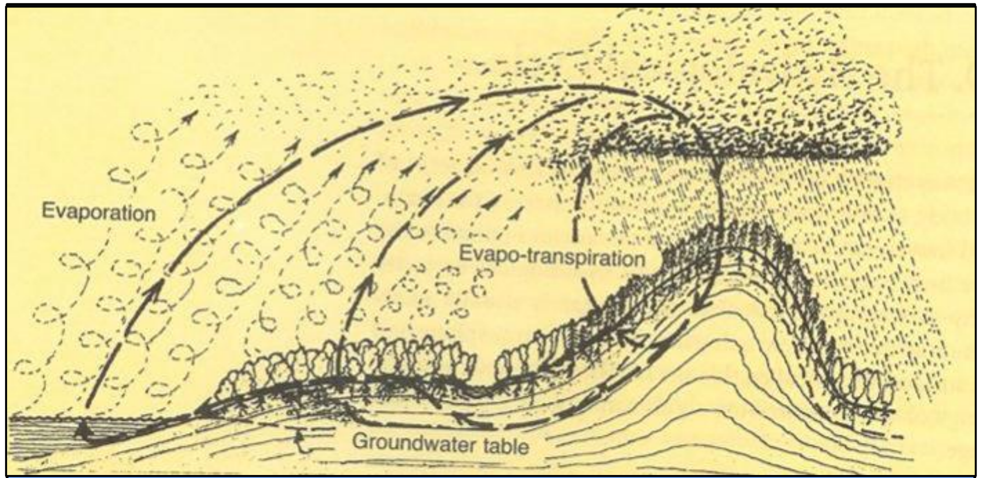
Change in the capacity of soil to store water (litres/ha) with changes in levels of soil organic carbon (OC) or humus to 30cm of soil depth.				
Bulk Density 1.2g/cm3				
Change in OC Level	Change in OC (kg/m2)	Extra water (litres/m2)	Extra water (litres/ha)	CO_2 Seq. (t/ha)
1%	3.6	14.4	144,000	132
2%	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)				

Student Exercise:
From the above table, extrapolate the potential CO_2 sequestration for your country and region, then briefly discuss your findings.

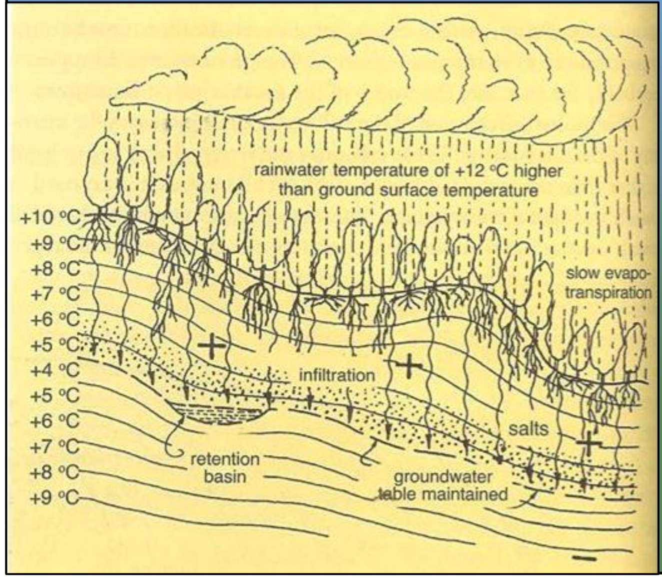
The Hydrological Cycle

The full hydrological cycle illustrated in the adjacent figures shows the cycle of evaporation from oceans and evapo-transpiration from vegetation repeating itself continuously in a typical natural unspoilt landscape with significant biomass from trees. The impact of the full cycle is a moderate cycle of rising water vapour, cooling and condensing to form clouds, causing precipitation to fall as rain, which repeats itself constantly. This rainfall infiltrates the ground under a positive temperature gradient where the earth is cooler than the air above it. This allows the rainfall to soak into the earth and pass through the +4°C layer where groundwater is maintained and also where purification takes place at this temperature. The groundwater, in turn, is in a constant cycle of downward and upward movement, with the heavier newer water sinking and the warmer older water rising due to the heat from the earth's crust. This filtering of groundwater is akin to the filtering of blood through the liver and kidneys. This groundwater cycle allows the purification of water and the uptake of minerals and nutrients through the roots of plants, with subsequent evapo-transpiration and precipitation allowing the dispersion of earth's minerals and nutrients over a wide area, thereby maintaining biodiversity and biomass.

The Full Hydrological Cycle



The Full Hydrological Cycle



A positive temperature gradient allows rainfall to soak into the ground and facilitates the nutrient and mineral exchange in the soil.

Source: Hidden Nature – The startling insights of Viktor Schauberger, by Alick Bartholomew

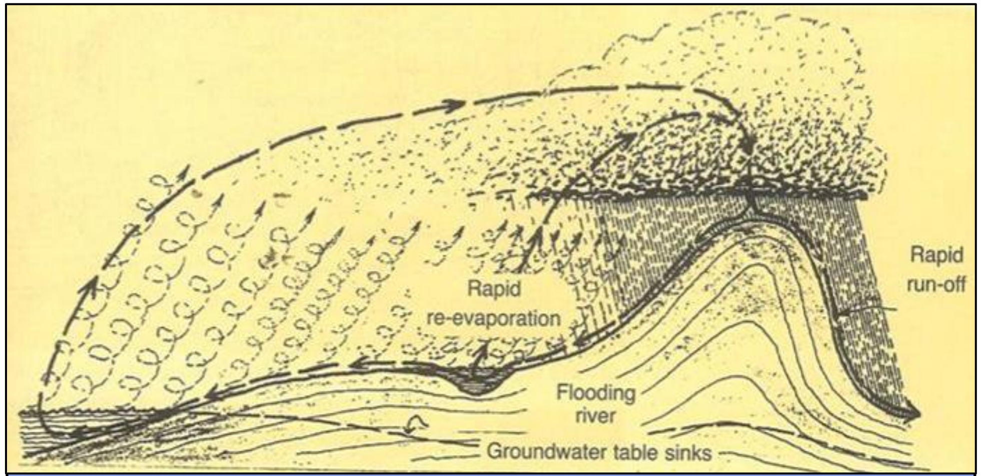
In contrast, the half hydrological cycle illustrated in the adjacent figures, shows only the evaporation from oceans repeating itself continuously in a typical disturbed landscape devoid of biomass from trees. This half cycle excludes the evapo-transpiration from vegetation. The impact of this half cycle is that the evaporation from the ocean still leads to rising vapour, cooling and condensation, formation of clouds, and precipitation falling as rain, albeit, with relatively greater energy exchange due to the increased air temperature. However, this rainfall does not penetrate the earth's surface, but rather causes rapid runoff over the ground surface, causing erosion. Consequently, there is very little water infiltration into the earth, no groundwater recharge, and, a sinking water table. In turn, this breaks the uptake of the mineral and nutrient cycle to plants. A major negative feedback loop, is the greater chance of flooding, excessively fast re-evaporation, and, oversaturation of the atmosphere with water vapour. Furthermore, because of the negative temperature gradient between the hotter earth and the cooler air above, the cooling and condensation is lifted higher and higher, with formation of storm cloud intensity, which often leads to huge storm downpours with accompanying large hailstones. Meanwhile, the hot baking surface, sucks up the water table and with it the rising salts, which clog up the surface of the earth and seal it from water penetration.

To summarise, the half hydrological cycle is made up of long hot dry spells, followed by quick intense precipitation, compared to the regular and balanced full hydrological cycle where rainfall is moderated and then purified through the earth as the groundwater is recharged, and then released through evapo-transpiration through plants, together with minerals and nutrients. From this comparison, one can conclude that it is essential to restore the full hydrological cycle in order to restore biocapacity in the landscape.

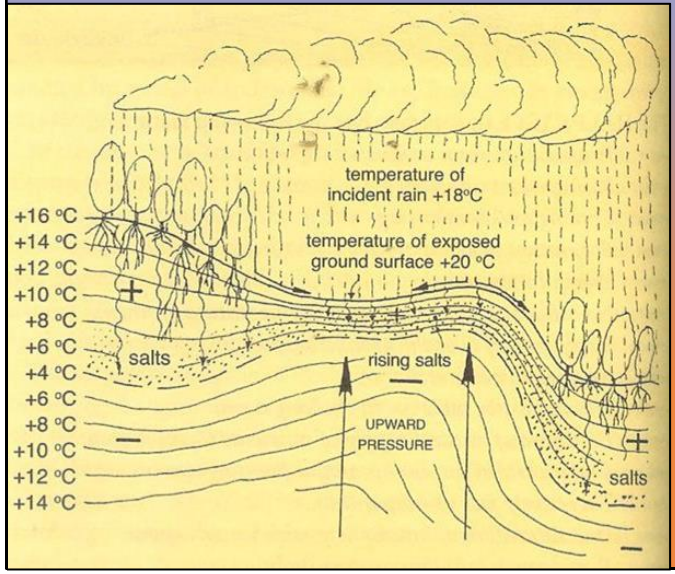
For more information, see this short video (8 mins), or a longer documentary (1 hour 15 mins) about the work of Viktor Schauberger entitled, "Comprehend and Copy Nature".

Source: Hidden Nature – The startling insights of Viktor Schauberger, by Alick Bartholomew

The Half Hydrological Cycle



The Half Hydrological Cycle



A negative temperature gradient hampers rainfall infiltration into the soil and causes loss of topsoil and erosion.

Ecosystem Restoration

The integration of regenerative approaches, such as, gully restoration, Keyline rainwater harvesting, forest-belts / agroforestry and limited-tillage, plus, all the value adding from specific soil enhancements and plants species, all have complementary benefits with a larger impact that if implemented individually. In other words, the whole systems approach is greater than the sum of its parts, which is the fundamental nexus of Permaculture. To this end, Permaculture inspired farms are producing not only food crops, but also providing invaluable ecosystem services. Permaculture farmers are therefore not only farmers, but also land stewards, with due financial rewards (see adjacent). Having demonstrated its effectiveness in agriculture, from backyard food gardens to large-scale farms, Permaculture is being adopted, whether explicitly or implicitly, in many large scale ecosystem restoration projects throughout the world (see adjacent samples).

Source: Paani Foundation and Video (12 mins)

Source: Greening the Desert Project and Video (4 mins)

Source: Forest Landscape Restoration, Ethiopia and Video (4 mins)

Source: Loess Plateau, China and Video (4 mins)

Source: Savory Institute and Video (22 mins)

Source: Tamera, Portugal and Video (4 mins)

Many farmers who value the nexus between humus rich soil, clean water and biodiversity, have realised this establishes the foundations for resilience and a profitable enterprise, besides them becoming land stewards that add value towards the sustainability triple bottom line of environmental, economic and social objectives.

These regenerative farms are also beginning to attract ethical investors who are keen on supporting sustainable forms of agriculture that mitigate climate change through opportunities for carbon sequestration. Some entities are positioning themselves to offer a service to connect farmers with carbon investors, and then validate the amount of carbon sequestration and additional farm income, such as:

REGEN NETWORK

Earth Restoration™

Outback Carbon

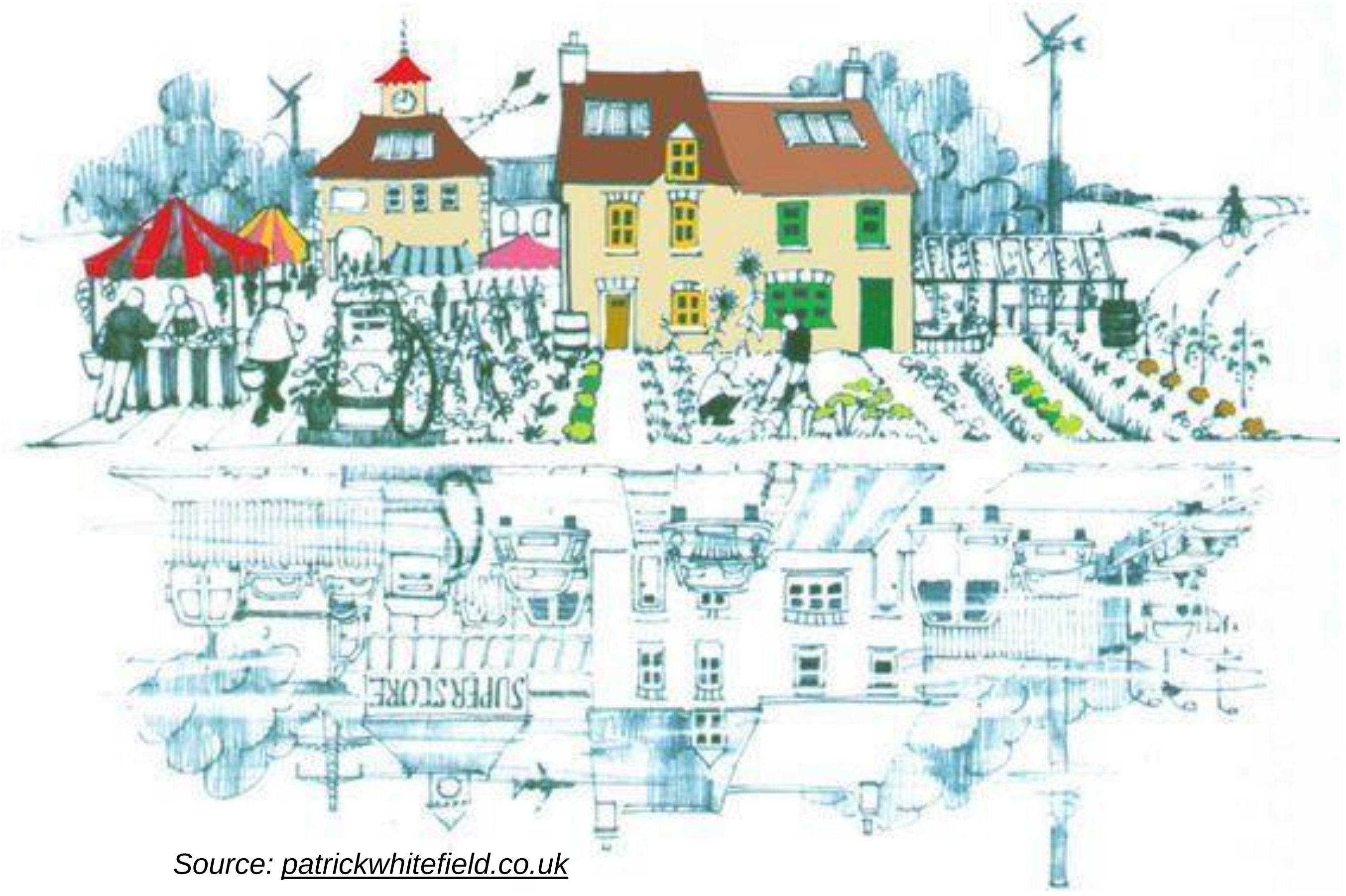
3. Permaculture solutions for the Built Environment to mitigate to Climate Change

3.1 Context

3.2 Sustainable Building Design Strategies (3-D)

3.3 Sustainable Spatial Strategies (2-D)

3.4 Sustainable Design Integration



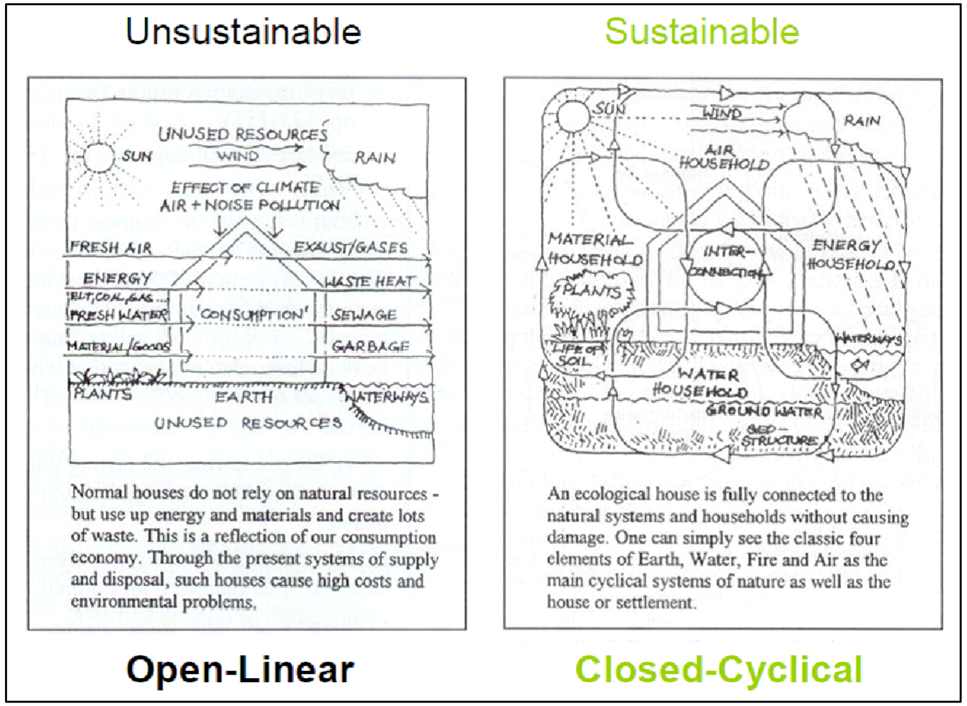
Source: patrickwhitefield.co.uk

3.1 Context

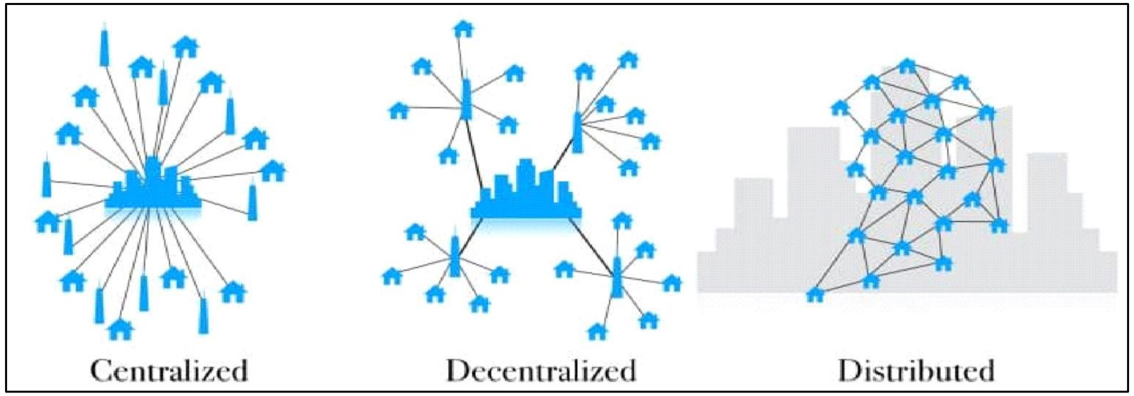
As background, the built environment has a significant impact upon the ecological footprint, as evidenced from the Earth Overshoot Day, thereby exacerbating climate change. The design for sustainability within the built environment is necessary, given that, the ***global average impact of the built environment and its operational uses, is estimated to use: 18% of the planet's use of fresh water; 25% of the wood consumed; 40% of fossil fuels, and, 27% of energy generated***. The adoption of sustainable design principles in the built environment sector will therefore make a significant impact to contribute towards climate change mitigation and adaptation. This is particularly relevant wherein the rural to urban migration is creating significant pressure on the built environment to utilize available resources in a sustainable manner, especially with the world population expected to reach 9 billion by 2050, with an estimated 70% living in urban areas, an increase from 46% in 2015 (Source: Global Footprint Network).

This section explores sustainable design solutions for the built environment which are inspired by Permaculture principles in two aspects, namely, the **vertical 3-D** and **spatial 2-D** (see adjacent figures). In other words, the form, shape and purpose of a building itself needs to be firstly designed according to sustainable design principles, but also, its spatial relationship to other buildings, the surrounding landscape and service networks.

3-D Comparative patterns for newbuild and retrofit



2-D Comparative patterns of infrastructure, utilities and services



Global Footprint Network®
Advancing the Science of Sustainability

Student Exercise:
What is the Ecological Footprint of the Built Environment for your country, and briefly discuss your findings.

Global Development Research Centre calculated the ecological footprint of **Tokyo** metropolitan area. It turned out to be almost three times the land area of Japan as a whole. Meanwhile, the ecological footprint of **London** is 120 times the area of the city itself, almost the entire UK.

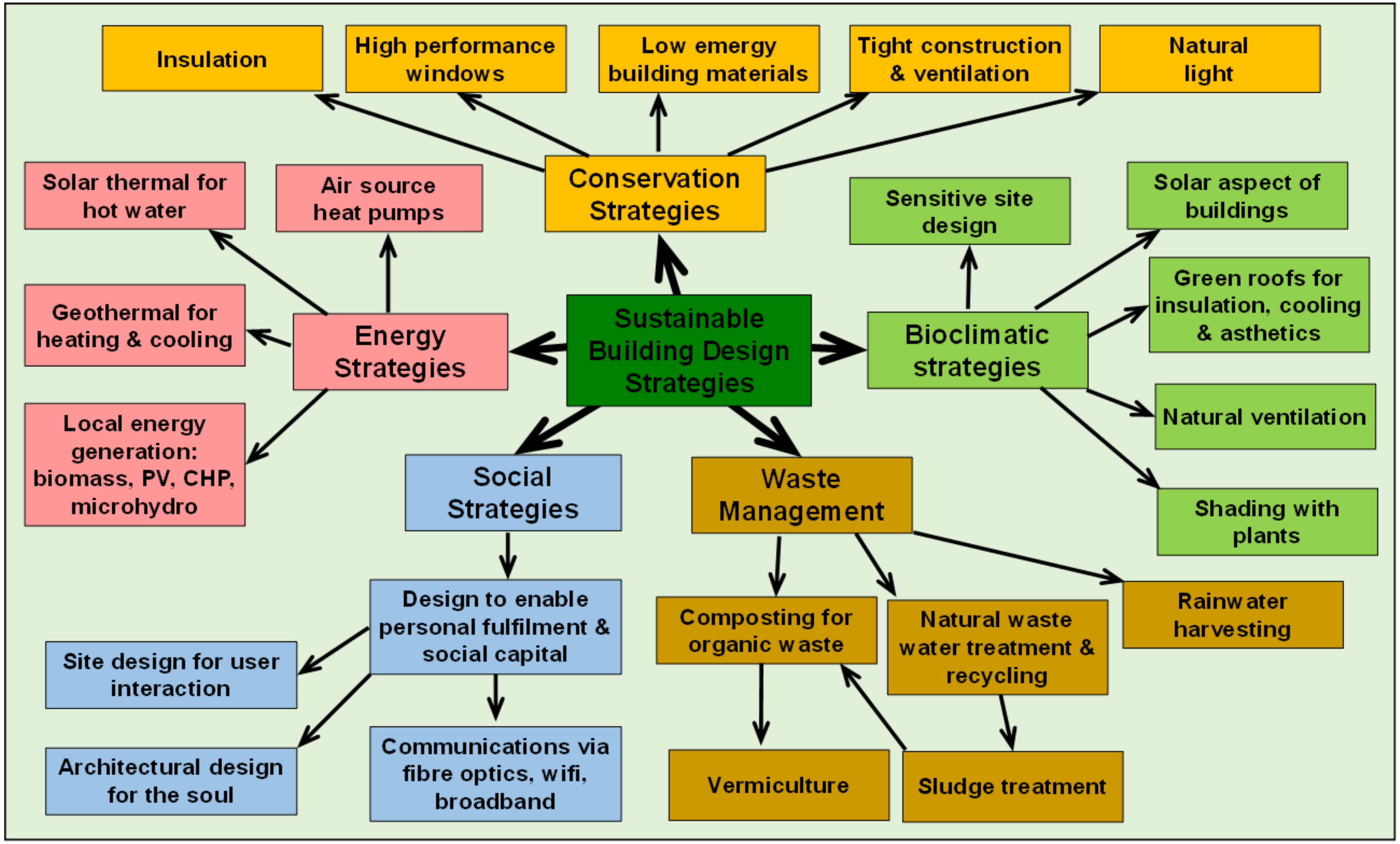
3.2 Sustainable Building Design Strategies (3-D)

The underlying Whole Systems Design Thinking approach, is further explored as Sustainable Building Design Strategies for both new-build and retrofitting of buildings, as shown adjacent, wherein five categories of design strategies are unpacked, namely;

- **Bioclimatic strategies** – intelligent design;
- **Conservation** – mainly around green building materials;
- **Energy** – aiming at carbon neutrality;
- **Waste management** – recycling solids and water as far as feasible;
- **Social strategies** – designed for community involvement as well as smart controls of technologies, broadband services and security.

Student Exercise:
Set up a template based upon the Sustainable Building Design Strategies for each component / sub-component, for a basic assessment (Score of 1 to 5) that can be undertaken for your own home. Undertake a basic assessment (your opinion score out of 5) for each component / sub-component. Motivate which component is the most appropriate and value for money retrofit investment for your home.

Sustainable Building Design Strategies



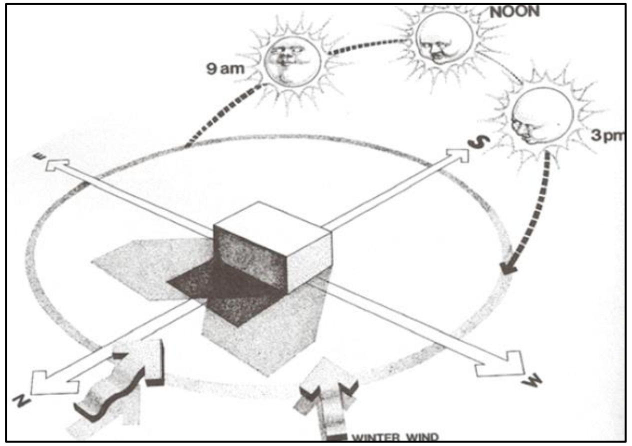
Bioclimatic Strategies

Bioclimatic strategies are a key element of designing sustainable houses. The aspect (relative position) of the building to the arc of the sun along with attention to specific site conditions is paramount in order to create an ecologically intelligent design. Where heating is a key issue, a passive solar design will determine the aspect of the building to the sun. Where cooling is an important consideration, landscaping can provide shading and the wind natural ventilation. More specifically;-

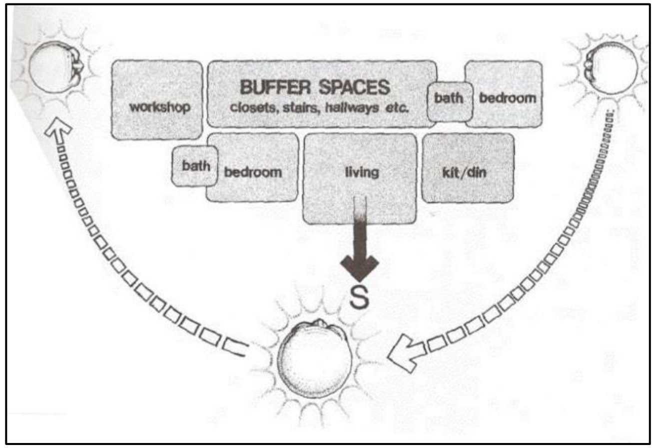
Sensitive site design attempts to minimize environmental disturbance by taking cognizance of; weather influences of sun, wind and rain; niche microclimates; site hydrology, topography and geology; and, site flora and fauna.

Solar aspect of buildings or passive design is about building aspect to maximise solar gains asper the adjacent illustrations, with solar harvesting designs using thermal mass of masonry and rock beds, as well as, air flow gaps. Active solar heating can be achieved by building thermal mass into the structure. Thermal mass combined with thermal insulation in a building buffers changes in the outside environment, thereby creating more even and comfortable conditions inside the structure. These processes can be enhanced with active systems, using fans and pumps.

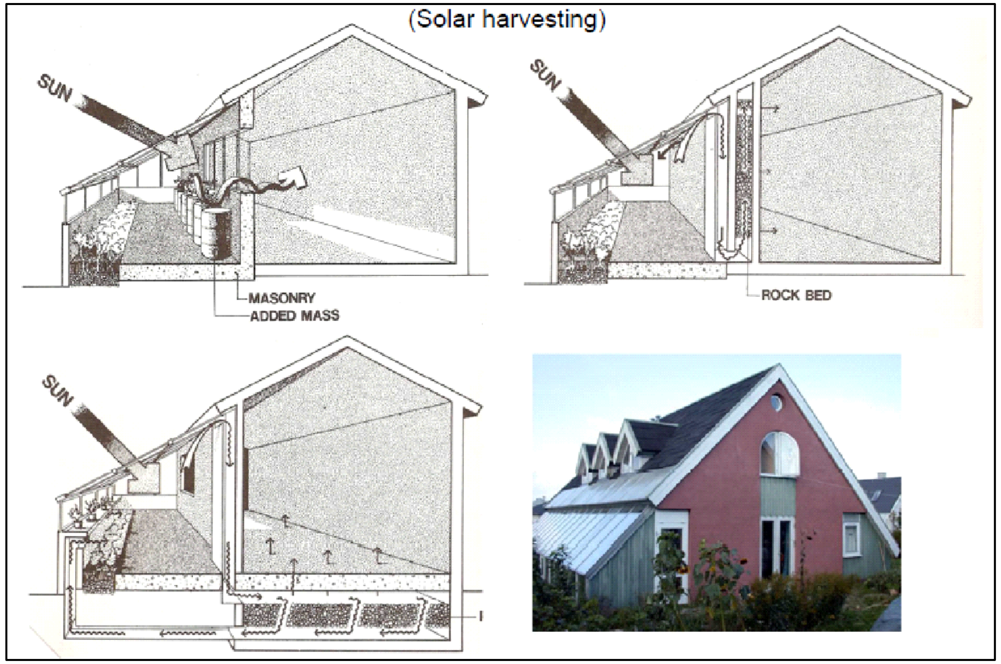
Northern hemisphere solar aspects



Functional planning for solar gain

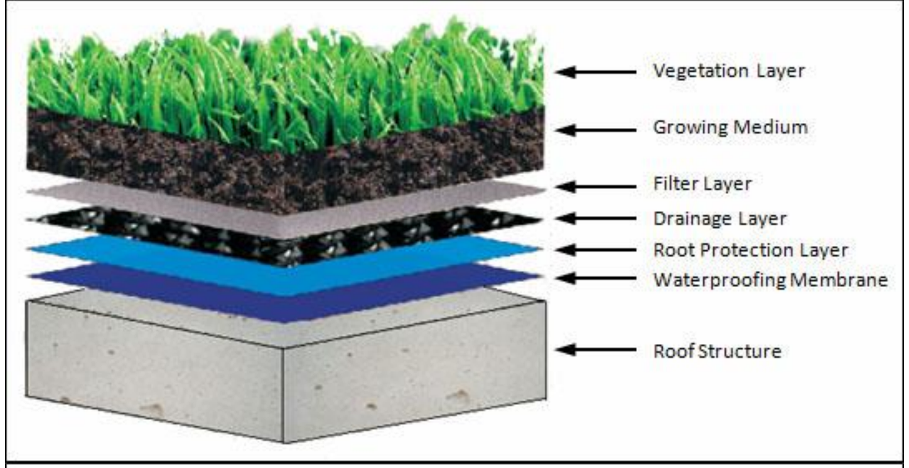


Design for solar gain



***Green roofs** for insulation, cooling and aesthetics* can provide extra insulation as well as aesthetics to a design. Many green roofs absorb the sun's energy as opposed to reflection and can reduce the ambient temperature within an urban district. A good option for green roof plants is sedum or to allow the natural surrounding grasses to establish themselves. However, regular maintenance of the green roof is essential in order to remove any shrubs or tree seedlings which take root. A typical green roof design in the figure below shows the various layers that make up a good design detail which ensures that the roof structure remains waterproof. The green roof design around the verges and gutters is usually quite challenging, but again, the details must ensure that excess rainwater is adequately drained away at all times.

Green roof design detail

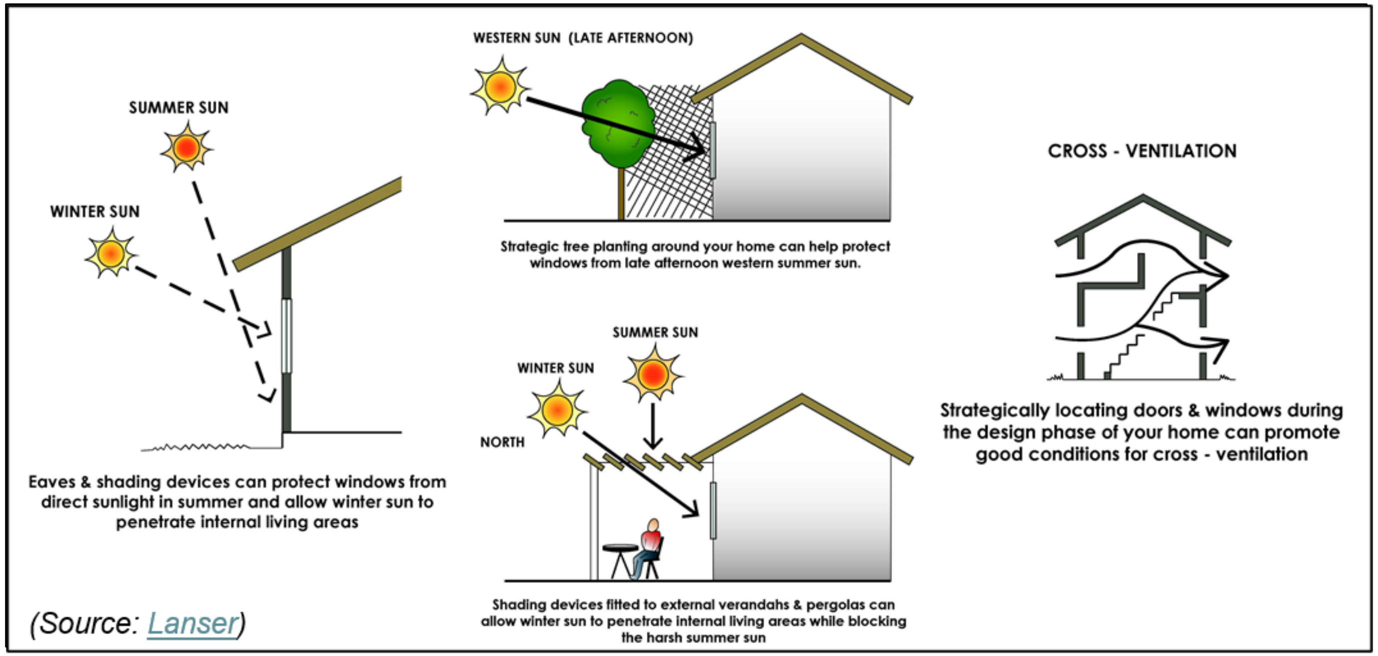


Rooftop Landscapes incorporate a system of layers of engineered linings

(Source: http://www.rooftoplandscapes.co.za/green.php)

Shading with plants is landscaping with deciduous trees and extended roof lines to provide shading for summer cooling, whilst low sun in winter through bare trees can provide passive solar heating. Similarly, pergolas with vines over verandas can provide much needed summer shading whilst in winter the leaves will fall and allow winter sunlight for warmth (see figure below).

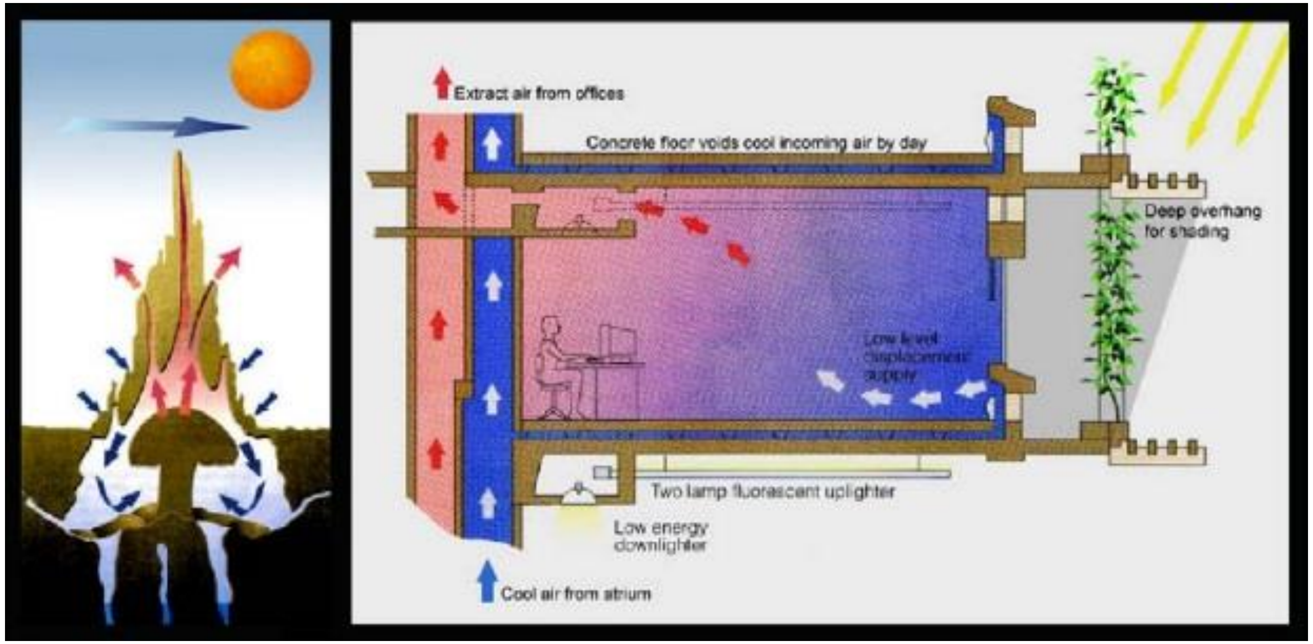
Shading with plants and awnings

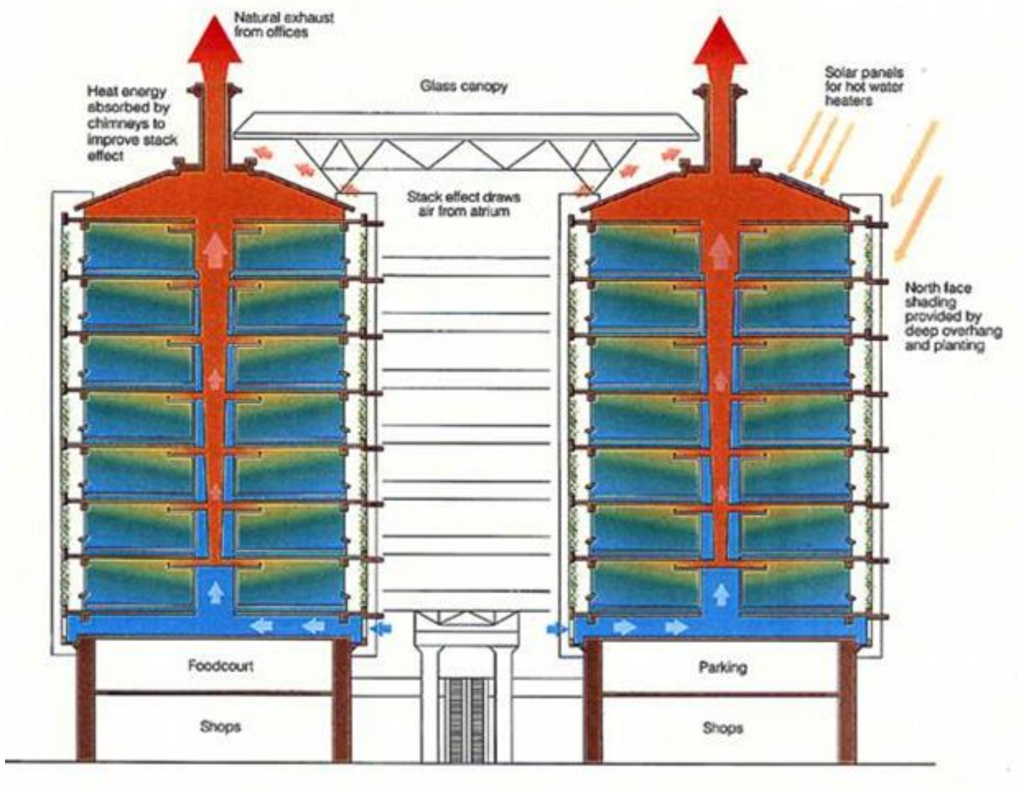


(Source: Lanser)

Natural ventilation is where it is necessary to have forced air ventilation for bathrooms and kitchens. There are also useful techniques for passive or natural ventilation, for example termite ventilation (see short video), which can be applied depending on the specific site and climate. An iconic building which applied biomimicry to model termite ventilation is the Eastgate Centre in Harare, Zimbabwe, typifies the best of green architecture and ecologically sensitive adaptation. The country's largest office and shopping complex is an architectural marvel in its use of biomimicry principles.

Eastgate uses 35% less total energy than the average consumption of six other conventional buildings with full HVAC in Harare. The saving on capital cost compared with full HVAC was 10% of total building cost. During the frequent shut downs of mains power, or of HVAC due to poor maintenance in the other buildings, Eastgate continues to operate within acceptable comfort levels with its system running by natural convection.
(Source: Mick Pearce)



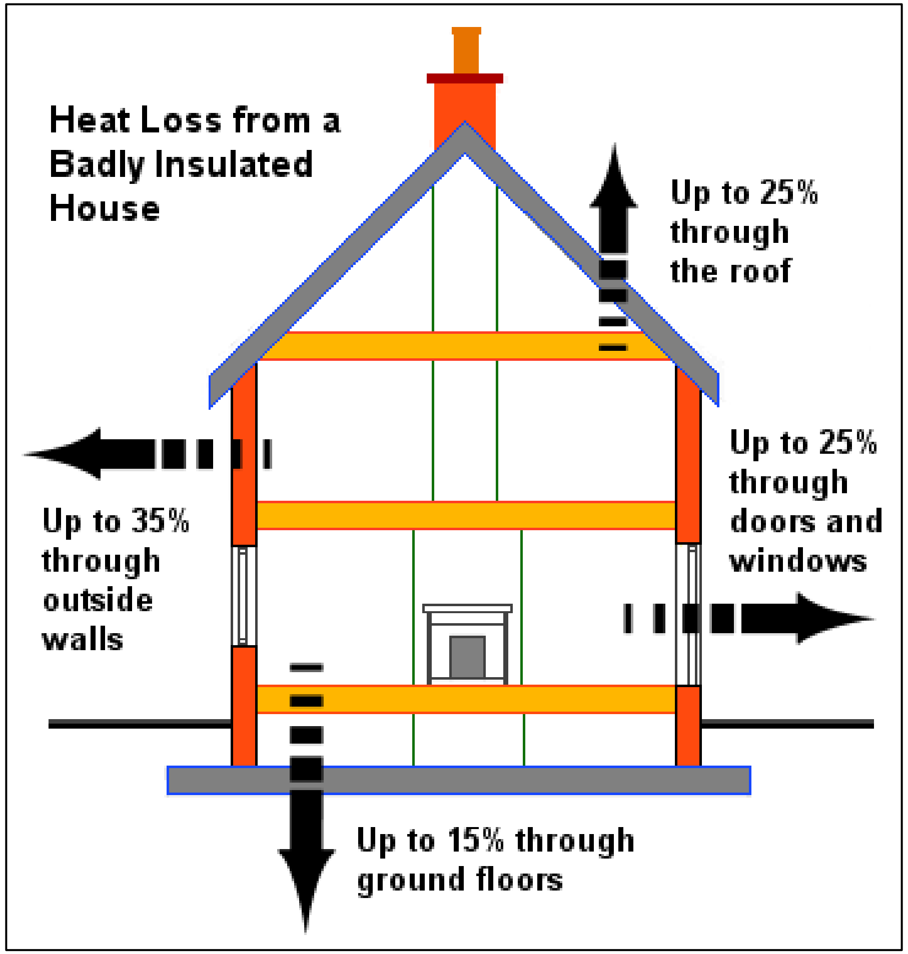


Conservation Strategies

Insulation is one of the most critical building design details in order to mitigate the ingress of moisture and dampness into a building. There are many places in a building which are prone to dampness and should therefore be addressed through proper insulation as illustrated in below. Many insulation materials can be made from natural materials, such as, rockwool, hemp, straw, cellulose fibre, etc.

High performance windows is an important design feature considering the relative window to wall ratio and the density of glass to various walling solutions. The relatively low glass density makes for a greater transfer of temperature difference between the external and internal components of a building compared to most walling densities. However, with double or triple glazing with inert gas seals, the air gap reduces heat transfer by conduction and convection, since air is a poor conductor and the air gap is too narrow for convection currents, respectively. However, with double or triple glazing with inert gas seals, the air gap reduces heat transfer by conduction (since air is a poor conductor) and convection (since the air gap is too narrow for convection currents). Furthermore, with Low-E, or low-emissivity glass, the amount of infrared and ultraviolet light that comes through glass is minimized without minimizing the amount of light that enters the building. Low-E glass windows have a microscopically thin coating, usually on the external face of the internal double glazing, which is transparent and reflects heat. The combination of double, triple glazing, Low-E glass and plant shading, all offers various combinations to reduce energy consumption of heating and cooling of buildings.

General heat losses in a building

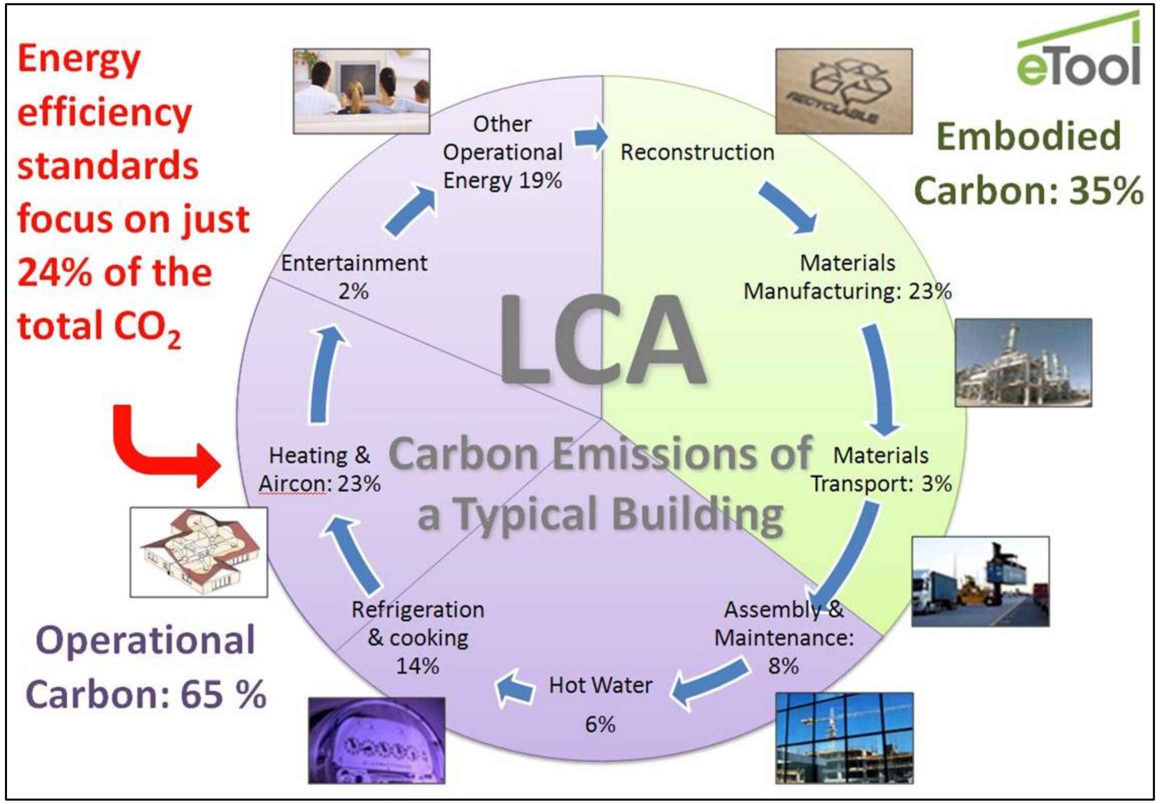


(Source: http://www.city-architecture.co.uk/sustainable-architecture/heat-loss-diagram/)

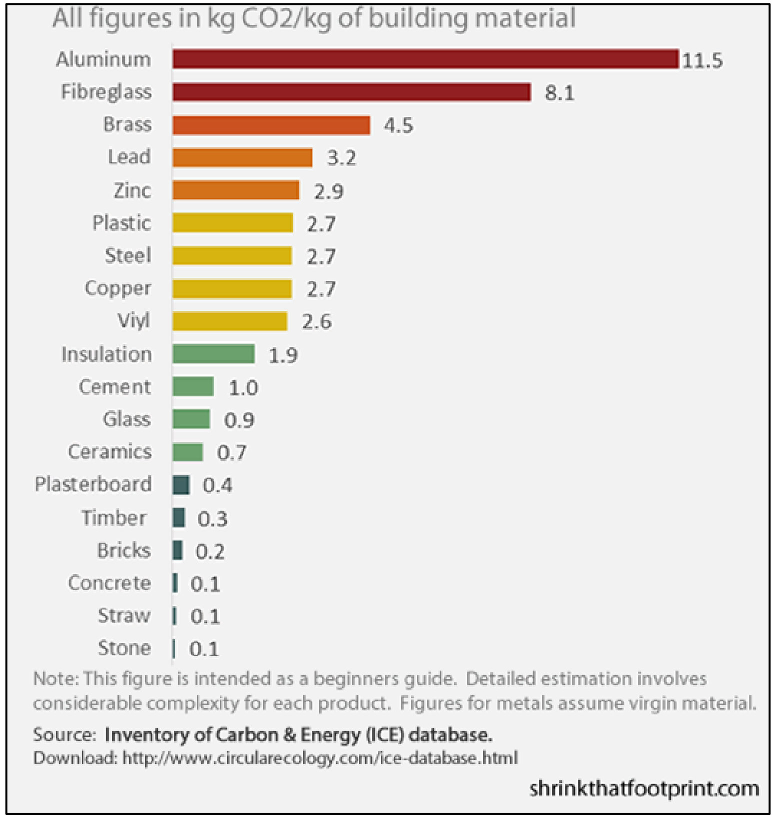
Building materials is the choice of materials with low emergy (embodied energy / carbon footprint, both initial and ongoing (see figure below) as a means to reduce the ecological impact of a building by doing a life-cycle analysis (LCA). The LCA in this figure shows that, generally, the total emergy of a building, is approximately 35% during the initial implementation and 65% during the ongoing lifetime operational and maintenance of the building. One should therefore design to minimize the impact for both during and post implementation.

Given that many buildings exhibit high ecological footprints, it becomes imperative to reduce this impact through the choice of various building materials. Using local materials from within the bioregion of a building project will contribute significantly towards reducing emergy values, especially through relatively low emergy materials such as: local wood, unfired clay bricks, rammed earth, cob, adobe bricks, stone masonry, local ceramics and tiles, local insulation (which might be sheep's wool, recycled paper, straw, hemp). See collage of "Building with Earth".

Life Cycle Analysis (LCA) – Embodied Energy ("Emergy")



Embodied carbon of some building materials



Meanwhile, materials with high emergy include: concrete, aluminium, steel, highly manufactured items, and, bulky materials sourced from great distances. The choice of building materials (see adjacent figure) is therefore an important factor in designing for carbon neutral buildings.

Tight construction and ventilation is a feature of construction details which requires attention to detail to ensure air tightness where heating is necessary, which makes a large difference to the energy budget. However, it is also necessary to have forced air ventilation for bathrooms and kitchens. There are also useful techniques for passive or natural ventilation, as per the termite ventilation described before. The form and shape of a building is also an important factor to consider when detailing construction joints and ventilation. A typical useful software design tool that can identify potential weakness in building design is "Autodesk Ecotect Analysis, which is an environmental analysis tool that allows designers to simulate building performance from the earliest stages of conceptual design. It combines analysis functions with an interactive display that presents analytical results directly within the context of the building model", as shown in a short video demonstration.

Natural lighting or daylighting is the efficient design to bring natural light into a building by using exterior glazing (such as, windows, skylights, etc.), thereby reducing artificial lighting requirements and saving energy, as illustrated in the adjacent figure.

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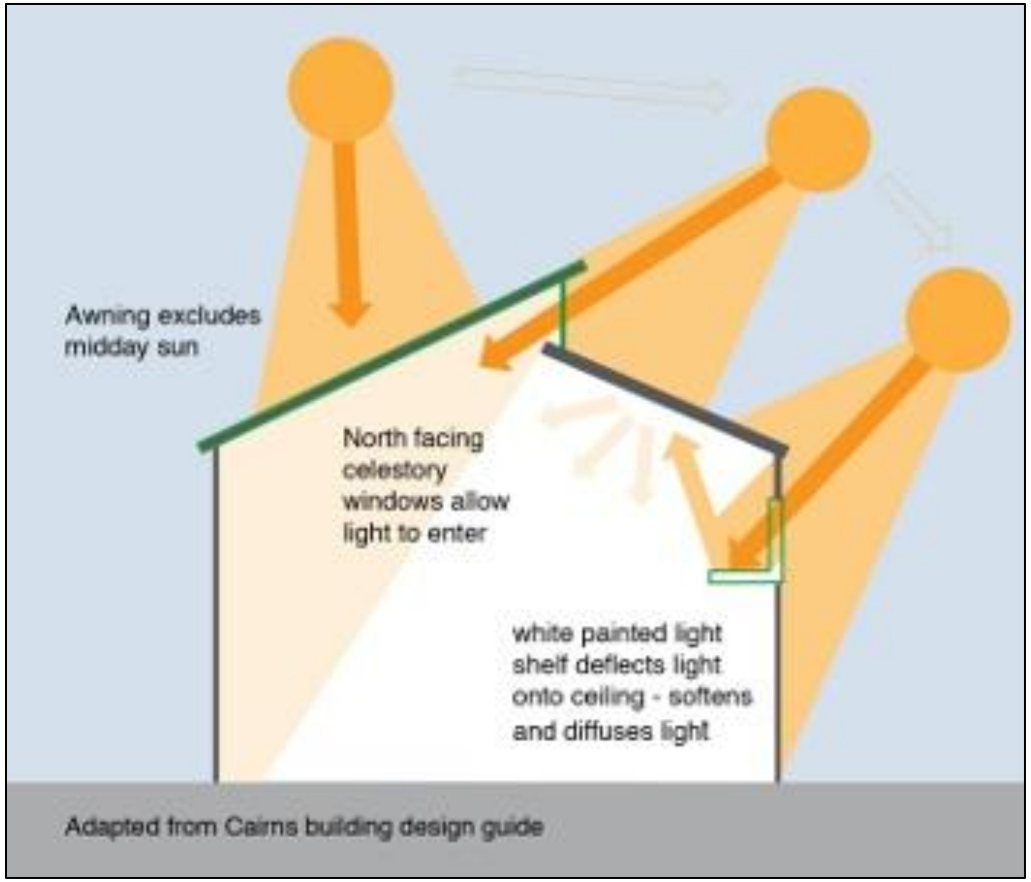
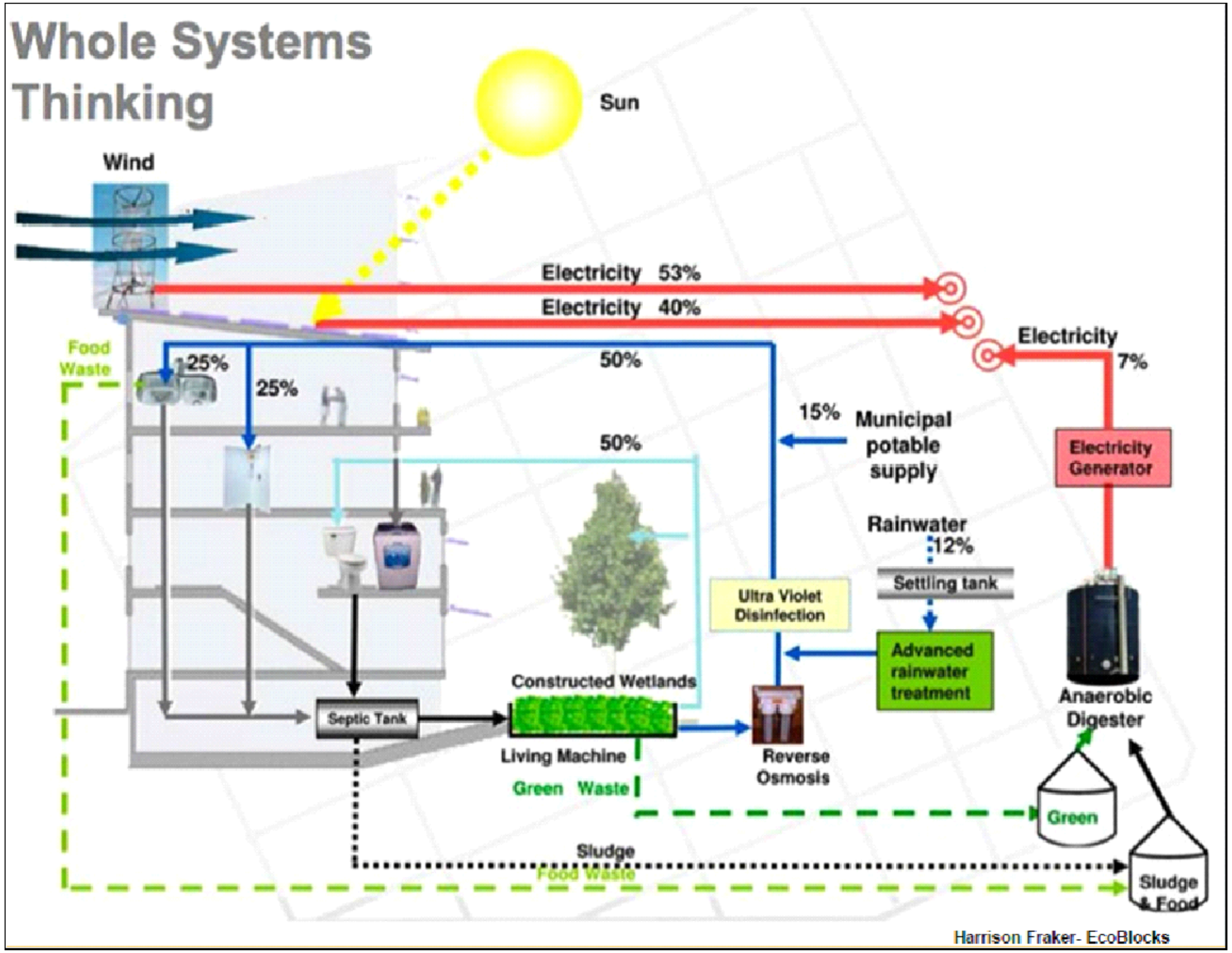


(Source: Unkown

Energy Strategies

The use of renewable energy systems follows cyclical ecological design thinking for both new-build and retrofitting of buildings for energy conservation. Herein, several building systems are integrated in order to maximise sustainability of the building, as illustrated in the adjacent figure. More specifically, energy supply is from wind, solar thermal, photovoltaic, biogas; water supply from municipal source, but augmented with rainwater harvesting and waste water treatment; and, an ecological sanitation system that recycles waste nutrients as compost and provides biomass for the biogas digestor. This ecological design reduces the negative waste impact and also the operational cost of utilities, such as, water, sewage, electricity and solid waste removal..

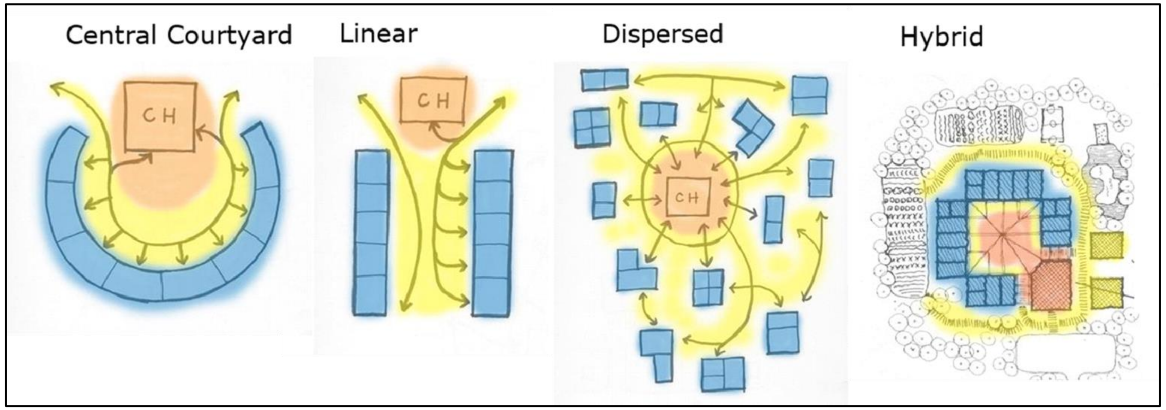


Social Strategies

Design to enable personal fulfilment and social capital can be facilitated through Cohousing / Ecovillage developments wherein the form and shape of facilities are spatially arranged to maximize social interactions and a community ethos along like-minded sustainable lifestyles. Furthermore, social interactions are planned among stakeholders as a collaborative design process with an emphasis on community governance and design integration of form and functional spaces (An insight into this collaborative design process can be explored at this weblink). This lays the foundation for Cohousing as a socially sustainable model which helps to build social cohesion and community capacity. It also empowers individuals, households and communities to address social, environmental and economic needs. Social strategies inform both the 3-D aspect as in the form and shape of Cohousing, and also, the 2-D aspect in the spatial layout form.

As a sustainability strategy, the Cohousing model can be seen as a microcosm of a future sustainable society wherein it can help transform design approaches for housing and urban development. The aspirations of Cohousing residents are social and not material-consumerist, and they are usually pro-actively involved in environmental action. Consequently, Cohousing residents generally live in smaller dwellings than ‘normal’; they share household and other consumer goods; they grow their own organic food in significant quantities; and, they also manage waste and recycling particularly well.

Site design for user interaction can be facilitated through Cohousing / Ecovillage developments that provide a balance between private, social and work spaces, whilst simultaneously reducing ones building footprint through sharing of facilities. The sustainability benefits of Cohousing demonstrates efficient land use through the clustering of dwellings and sharing of facilities, which in turn, frees up land for other purposes, such as, children’s playlot, small business workshop facilities, circulation space, food garden, etc. The sharing principles of Cohousing reduces the need for car ownership and associated parking spaces since a smaller pool of vehicles, albeit with a wider functionality, such as, motorbikes, small cars, delivery van, combi-bus, etc., can better service the community transport needs. Some of the generic concept plans for Cohousing layouts which create spatial opportunities for social interaction are shown in the figure below.



Generic concept plans for Cohousing layouts

Communications via WiFi, fibre optics and broadband are an emerging feature in "smart city" solutions wherein hyper-connectivity is becoming the norm. The European Commission defines smart cities as: "A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business. A smart city goes beyond the use of information and communication technologies (ICT) for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population".

However, "some experts believe that the notion of smart cities has been overly driven by hi-tech companies", for various reasons. These experts go on to say that, "Given this situation and the belief by some that the planning, design and construction of future cities requires an integrated approach to achieve successful outcomes, alternative terminology has been suggested. The term 'The Living City' refers to an approach in which technology plays an important but nevertheless supporting role (Ref Buro Happold: The Living City)".

Architectural design for the soul appeals to something beyond vernacular design and a sense of place, but also designing for a whole quality of life wherein the environment nourishes the soul. In his book, "Spirit and Place (2002, page187)", Christopher Day states this more poignantly as: "For wholeness – the basis of health – we need nourishment at every level. The complex and dynamic organization of the physical body underpins our relationship to spatial qualities. Life enhancing qualities around us support our life energies. Colour, harmony, multi-sensory delight support our feeling life, particular moods redressing personal and situational imbalances. … Buildings built upon these principles are buildings to nurture the whole human being".

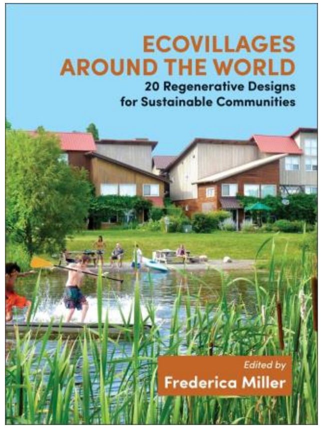
This echoed by David Pearson, founder of the Ecological Design Association in the UK and co-founder of Gaia International, an innovative group of ecologically responsible and inspired architects, believes that "far from expensive technological dreams, we need a down to earth vision – a future home integrated into a sustainable lifestyle for all of us." He argues: "Whether old or new, future housing will need to employ life-supporting systems. Materials, and spatial designs that meet the health, conservation and spiritual criteria" (Pearson, 1998, p.57) listed in the 'Gaia House Charter'. The box below is list of criteria for holistic sustainable building was drawn up by the members of Gaia International. Many such houses have already been built and many old existing structures have been converted with these principles in mind. These are the beginnings of a complete transformation of the existing building stock to meet the long-term requirements of sustainable living.

The Gaia House Charter for Healthy and Sustainable Building
(Reproduced and adapted from Pearson, 1998, p.57)

Designing for Harmony with the Planet:
- Site, orient, and shelter the home to make best and conserving use of renewable resources. Use the sun, wind, and water for all or most of your energy needs and rely less on supplementary non-renewable energy
- Use green materials and products – non-toxic, non-polluting, sustainable, and renewable, produced with low energy and low environmental costs, and biodegradable or easily reused and recycled.
- Design the house to be intelligent in its use of resources and complement natural mechanisms, if necessary with efficient control systems to regulate, heating, cooling, water, airflow and lighting.
- Integrate the house with the local ecosystem, by planting indigenous tree and flower species.
- Compost organic wastes, garden organically, and use natural pest control – no pesticides.
- Recycle greywater and use low-flush or waterless toilets. Collect, store, and use rainwater.
- Design systems to prevent export of pollution to the air, water, and soil.

Designing for Peace and Spirit
- Make the home harmonious with its environment – blending in with the community, the building styles, scale and materials around it.
- Participate with others at every scale, using personal ideas and skills of all in order to seek a holistic living design
- Use proportions, forms and shapes that are harmonious, creating beauty and tranquillity.
- Use colours and textures of natural materials and natural dyes, paints, stains to create a personal and therapeutic colour environment.
- Site and design the house to be life enhancing, and increase the wellbeing or vital force chi, of its occupants.
- Connect the home with Gaia and the natural world and the rhythms and cycles of the Earth, its seasons, and its days.
- Make the home a healing environment in which the mind and the spirit can be free and flourish.

Designing for Health of the Body
- Create a healthy indoor climate by allowing the house to breathe, and use natural materials and processes to regulate temperature, airflow and quality.
- Site the home away from harmful EM [electro-magnetic] radiation from power lines and also away from negative ground radiation. Design to prevent the build-up of static and EMF [electro- magnetic fields] from domestic equipment, and to avoid interference with beneficial cosmic and terrestrial radiation.
- Provide safe and healthy air and water, free from pollutants (radon especially), with good humidity, negative-ion balance, and pleasant fragrance from herbs, materials, and polishes. Use natural airflow and ventilation.
- Create a quiet home, protect and insulate from external and internal noise, and a pleasant, sound- healthy environment.
- Design to allow sunlight and daylight to penetrate, and thus rely less on artificial lighting.



(Source)

GEN EUROPE
GLOBAL
ECOVILLAGE
NETWORK


BedZED, London, UK (Source)

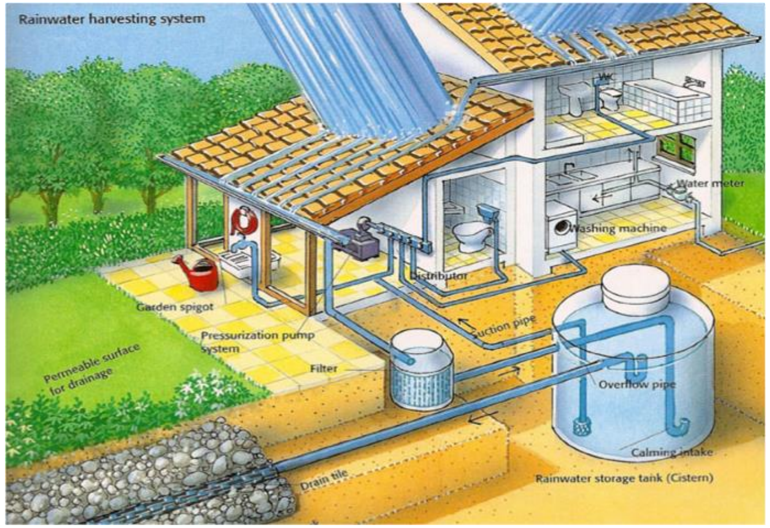

Findhorn Ecovillage, Scotland (Source)

Waste Management Strategies

Domestic rainwater harvesting systems that supply storage and use are a critical design element in any sustainable water system, as illustrated in the figure below. Rainwater is typically collected from roofs and stored in tanks adjacent to houses. Usually the first amount of rain after a dry period is flushed to the ground in order to clean the water collecting surfaces from dirt and any organic material from plants and animals that might have collected during a dry period.

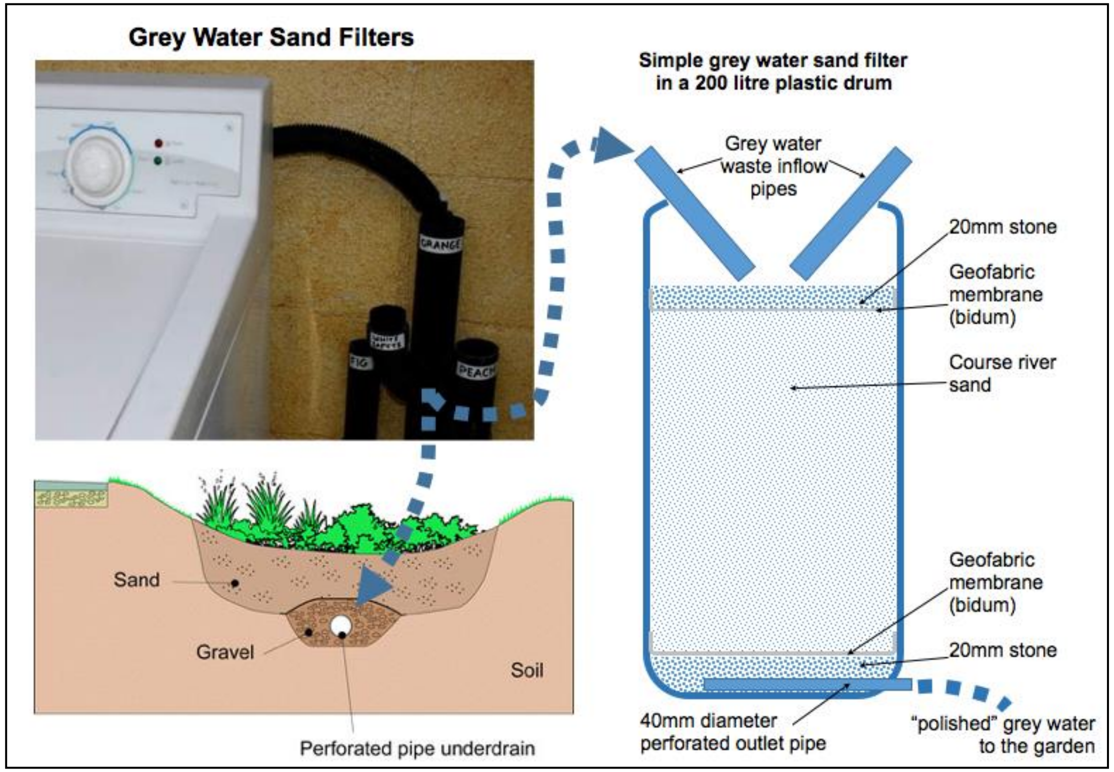
Often a sand filter is used between the storage tank and the house. This can be backflushed every year with water pressure. In this scenario, rainwater is used for domestic purposes (washing machines and toilets) and in the garden. However, in some countries (e.g. Australia) rainwater harvested from roofs is commonly used as drinking water. In some countries (e.g. Thailand) using rainwater for drinking water is the norm. When necessary, water can be purified using UV light or a charcoal filter.

Domestic rainwater harvesting



Greywater sand filters are relatively easy to construct in order to recycle waste water from a bath, shower and washhand basin, as illustrated in below. Often a sand filter is used between the storage tank and the house. This can be backflushed every year with water pressure. In this scenario, rainwater is used for domestic purposes (washing machines and toilets) and in the garden. However, in some countries (e.g. Australia) rainwater harvested from roofs is commonly used as drinking water. In some countries (e.g. Thailand) using rainwater for drinking water is the norm. When necessary, water can be purified using UV light or a charcoal filter.

Grey water sand filters



Natural waste water treatment: For sustainable solutions in lieu of the highly wasteful waterborne sanitation system and also many industrial waste streams, the ecological solutions are embedded in the use of "Nature's tool box", which elements is typically plants, microorganisms, filtering animals and fungi. Herein, these elements work in a symbiotic manner by breaking down and decomposing waste material, or simply put, the waste of one process is the food of another. More specifically, the bacteria break down the long-chain organic molecules into simple non-polluting substances. A small amount of nutrients – nitrogen and phosphorus – is taken up by the plants, which is typically less than 5% of the treatment. It is the root mass of the plants that is important since it provides the biofilm habitat for many elements. The elements within Nature's toolkit and the biofilm habitat is shown in the photo collage below.

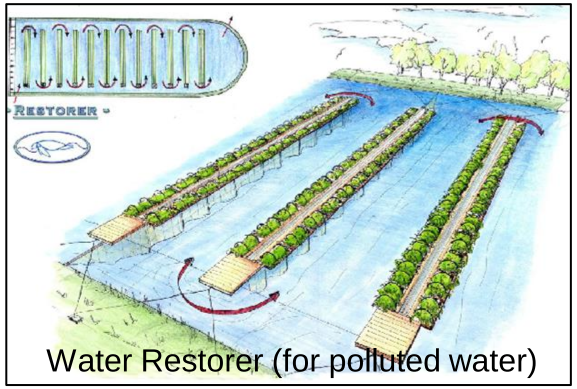
Elements in Nature's toolkit

Ecological sanitation, as in compost toilets, provide a dry solution that contains all sewage waste which is slowly composted. Meanwhile, waterborne sewage requires an initial process to settle the solids, which are usually broken down through an anaerobic process, such as, a septic tank or biogas digestor. The foul water (also known as black water) requires further treatment, usually through an aerobic process, such as, a constructed wetland, living machine or Wetland Ecological Treatment (WET) System, and in accordance with available space or specific circumstances, as illustrated below.

Application of waste water treatment systems


Living Machine (for limited spaces)


Constructed Wetland (for ample spaces)



Water Restorer (for polluted water)

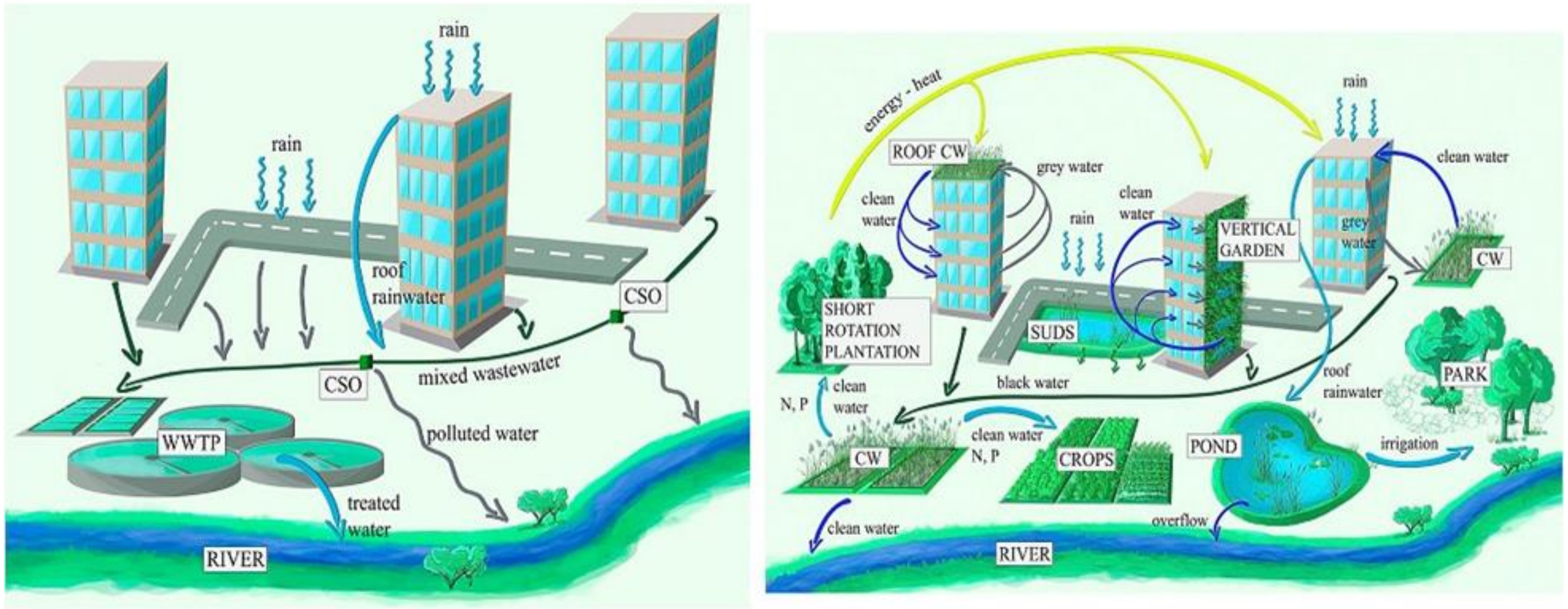

Wetland Treatment System (WET)
(for ample spaces)

3.3 Sustainable Spatial Strategies

This section explores some 2-D Sustainable Spatial Strategies for the built environment that support and enhance the 3-D Green Building Strategies. The 2-D spatial plane involves the town planning for the built environment land use parcels (housing, public realm, commercial, industrial, environmental and all servitudes); provision of utility services (water, sewage, solid waste and energy), transport (rail, road, water and air) and intermodal ports (harbours, transport terminals and warehouse logistics). It is an important concept to grasp that sustainable design for the built environment occurs both in a 3-D vertical space and also in a horizontal 2-D spatial plane. In other words, the built environment provides a continuum from town planning, landscape design, urban design and architecture, from a 2-D to a 3-D aspect, respectively. In order to achieve sustainable design in this built environment continuum, a whole systems thinking approach and design integration at all levels is imperative. This section will thus explore the following concepts:

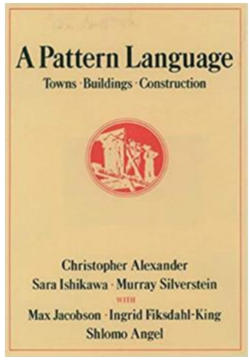
- A Pattern Language
- Integrated Infrastructure Systems
- Sustainable Drainage Systems
- Green Urbanism

Student Exercise:
Set up a template based upon the Sustainable Spatial Strategies for each component / sub-component, for a basic assessment (Score of 1 to 5) that can be undertaken for your own suburb, town or village.
Undertake a basic assessment (Score your opinion out of 5) for each component / sub-component.
In your opinion, outline which component is the most appropriate and value for money investment for your suburb, town or village.



Source: Unknown

A Pattern Language



One of the sources of inspiration for the design integration of the built environment, is the book, "A Pattern Language: Towns, Buildings, Construction", by Christopher Alexander et al. A website has been developed in order to expand the teachings from this book into a design language which shows the pattern relationships of the built environment. The following excerpt from this website provides the backdrop to the built environment design integration continuum:

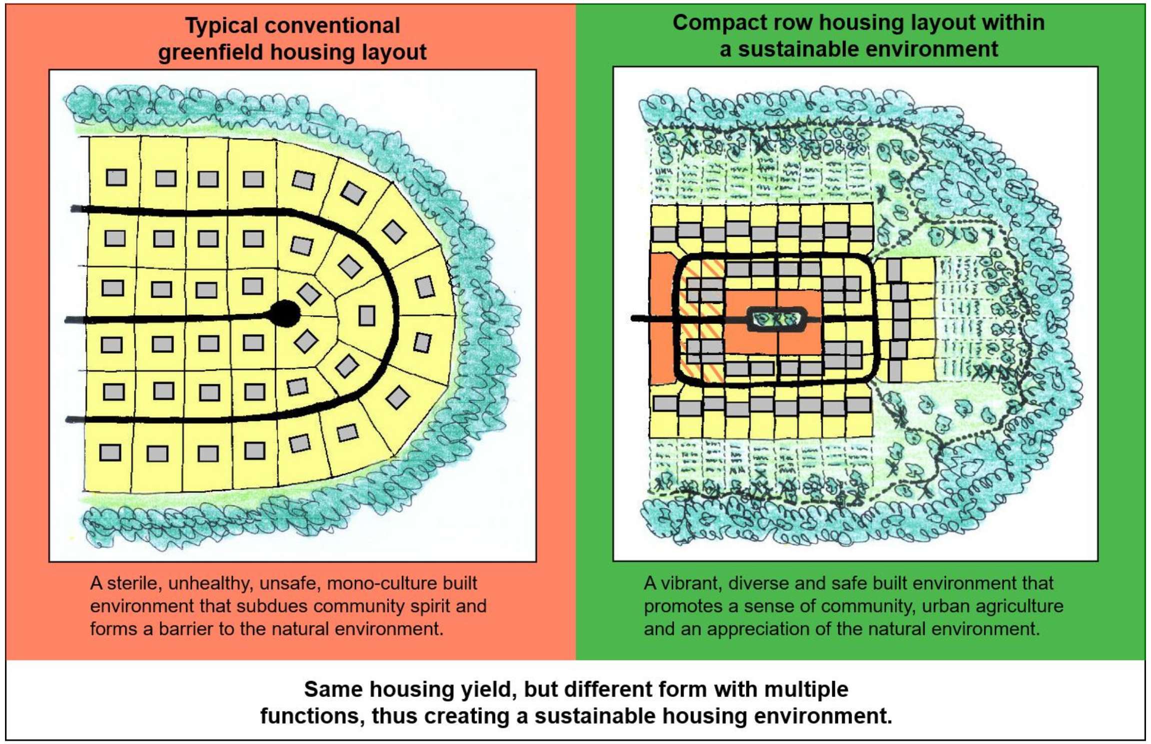
"Back in 1977, the book first introduced the concept of people designing buildings for themselves, and guaranteeing the comfort and functionality of the buildings they designed, because the elements of the language are "patterns", elements which are a collective memory of things which work in our surroundings. The language begins with patterns that define towns and communities. These patterns can never be designed or built in one fell swoop - but patient piecemeal growth, designed in such a way that every individual act is always helping to create or generate these larger global patterns, will, slowly and surely, over the years, make a community that has these global patterns in it.

The next part of the language gives shape to groups of buildings, and individual buildings, on the land, in three dimensions. These are the patterns which can be "designed" or "built" - the patterns which define the individual buildings and the space between buildings; where we are dealing for the first time with Patterns that are under the control of individuals or small groups of individuals, who are able to build the patterns all at once.

The next, and last part of the language tells how to make a buildable building directly from this rough scheme of spaces, and tells you how to build it in detail."

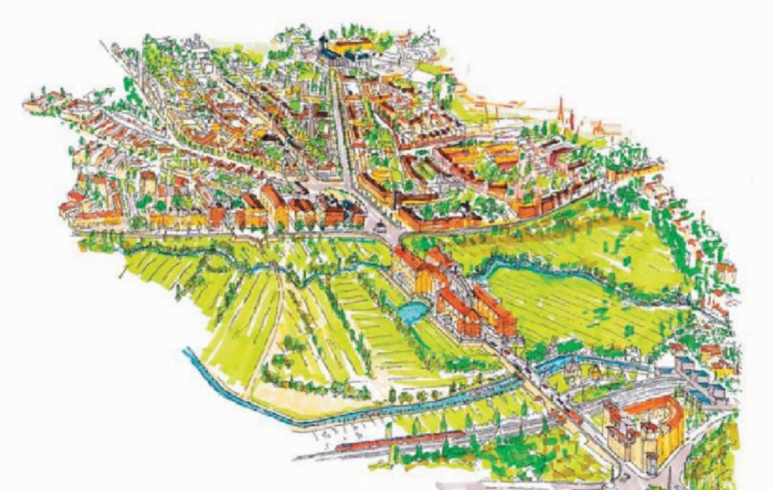
Alas, there is no perfect sustainable built environment, but nevertheless, there are many very good examples across the world where best practices have been developed and are being transferred to other regions. This section explores some of these approaches whose focus is on design integration. A typical introduction to the "Pattern Language" way of thinking is embodied in the illustration below that compares a conventional layout with a more wholistic integrated layout which both have the same number of housing units, but with much different characteristics.

Comparison of two housing layouts - conventional versus sustainable



Integrated Infrastructure Systems

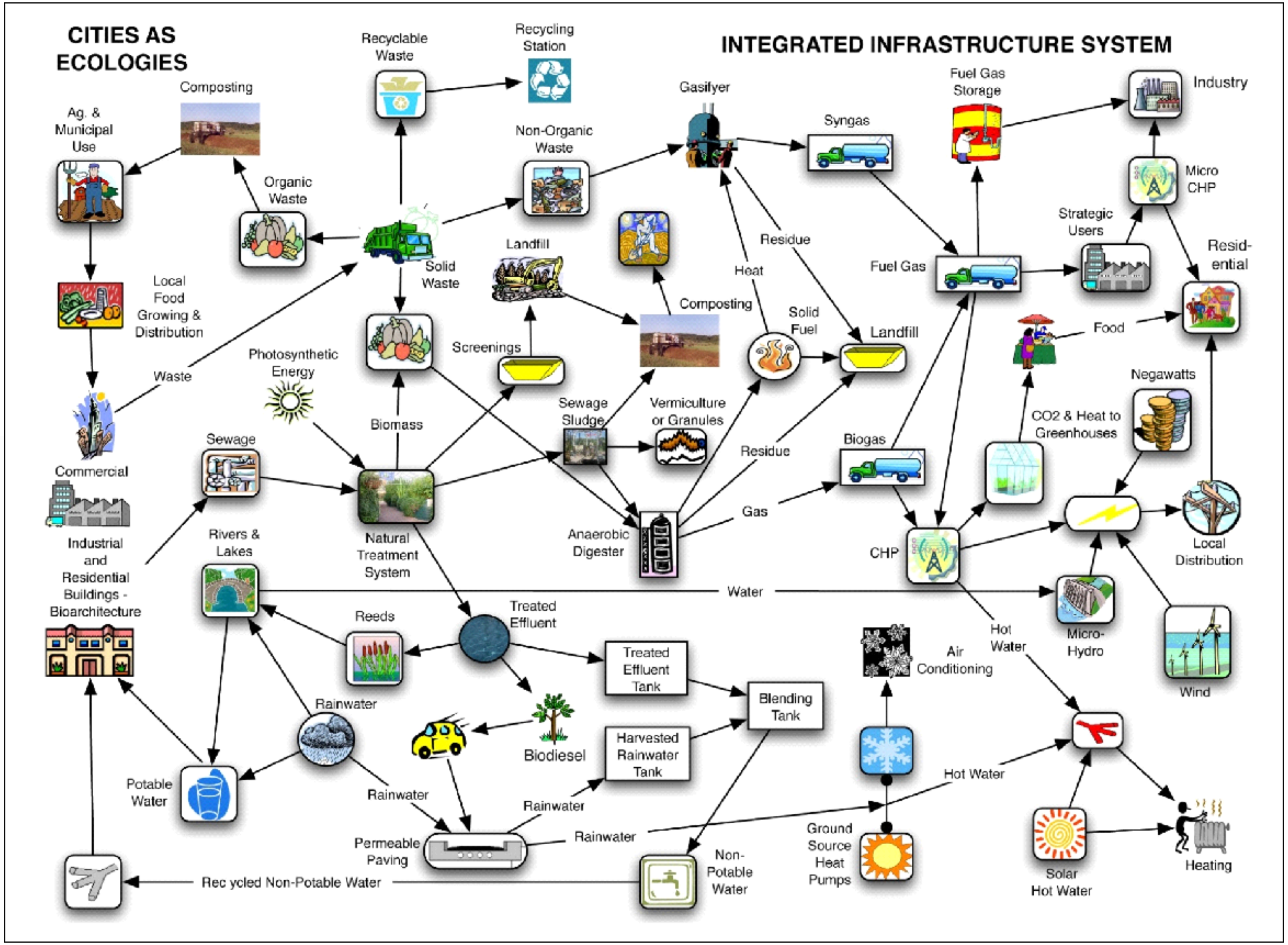
A concept example of an integrated infrastructure system is shown adjacent for a proposed development for Harlow North (UK). Herein, the overarching design protocol was simply to not abstract from aquifers more than half of the daily 90 litre per person water consumption quota. This design imperative resulted in a major closed loop design for the ensuing rainwater harvesting, stormwater drainage, waste water treatment, sewage, composting, biogas, etc., wherein the "waste" of one process is the "food" for another process.



HARLOW NORTH

Is this a development before its time?

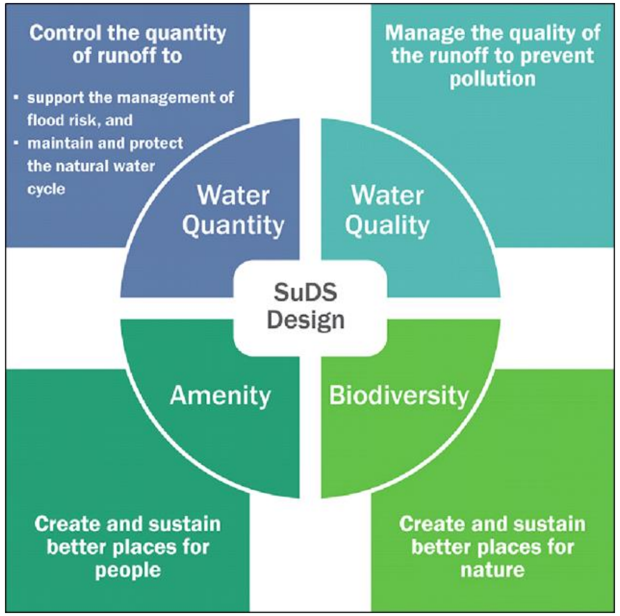
An example of an integrated infrastructure system for a proposed development for Harlow North (UK)



Sustainable Drainage Systems

A **sustainable drainage system** (SUDS) is designed to reduce the potential impact of stormwater surface discharges, especially severe rainstorms, for both new developments, as well as, the retrofitting of existing developments, as outlined in the SUDS design approach in the adjacent figures.

SUDS design approach



SUDS comparative example

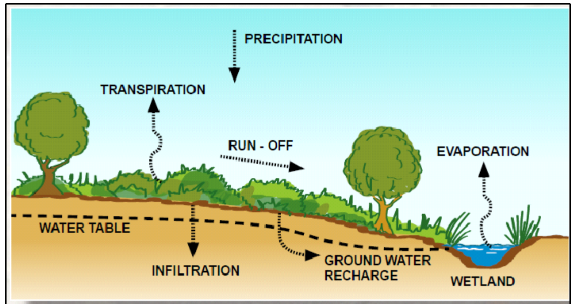


Figure 1: Natural hydrological system

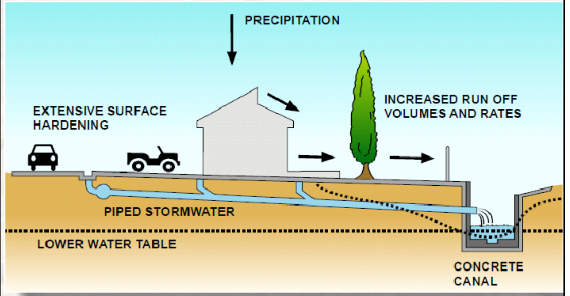


Figure 2: Stormwater management approach with little regard for the natural environment.

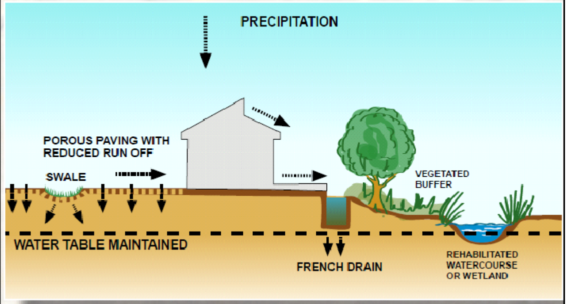
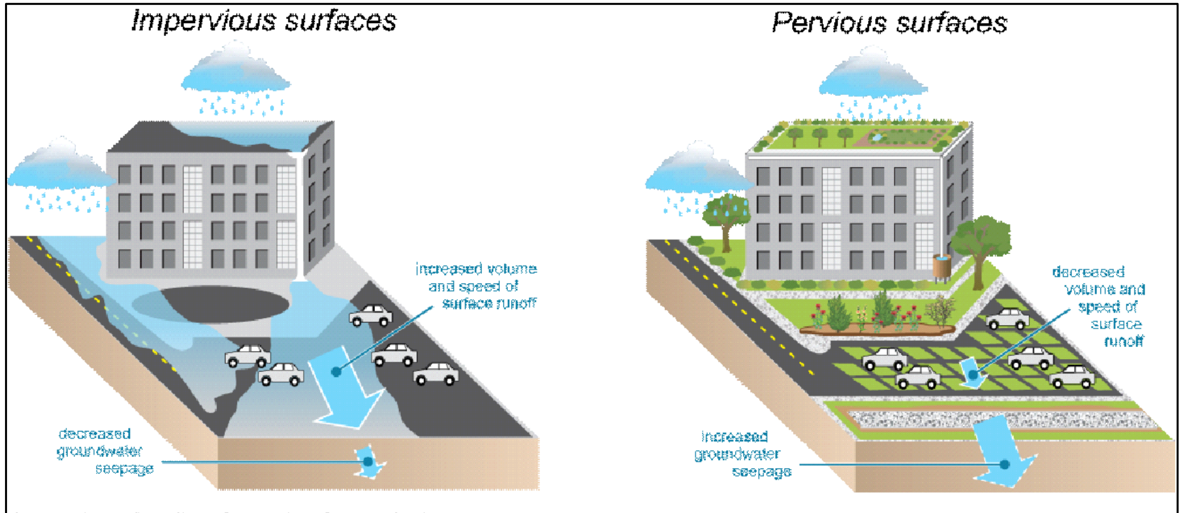


Figure 3: Responsible approach to stormwater management (SUDS).

SUDS is a closed loop system that slows down, spreads and sinks stormwater discharges, unlike conventional stormwater management which paves, pipes and pollutes stormwater runoff. This concept is illustrated in the adjacent figures which compares the natural hydrological system, a conventional engineered stormwater management approach, and, a responsible approach for stormwater management as in SUDS.

SUDS comparison of impervious and pervious surfaces



Impervious 'hard' surfaces (roofs, roads, large areas of pavement, and asphalt parking lots) increase the volume and speed of stormwater runoff. This swift surge of water erodes streambeds, reduces groundwater infiltration, and delivers many pollutants and sediment to downstream waters.

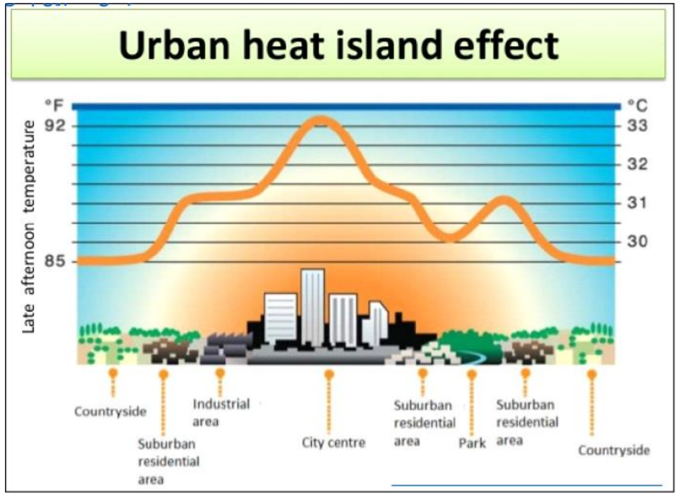
Pervious 'soft' surfaces (green roofs, rain gardens, grass paver parking lots, and infiltration trenches) decrease volume and speed of stormwater runoff. The slowed water seeps into the ground, recharges the water table, and filters out many pollutants and sediment before they arrive in downstream waters.

Green Urbanism

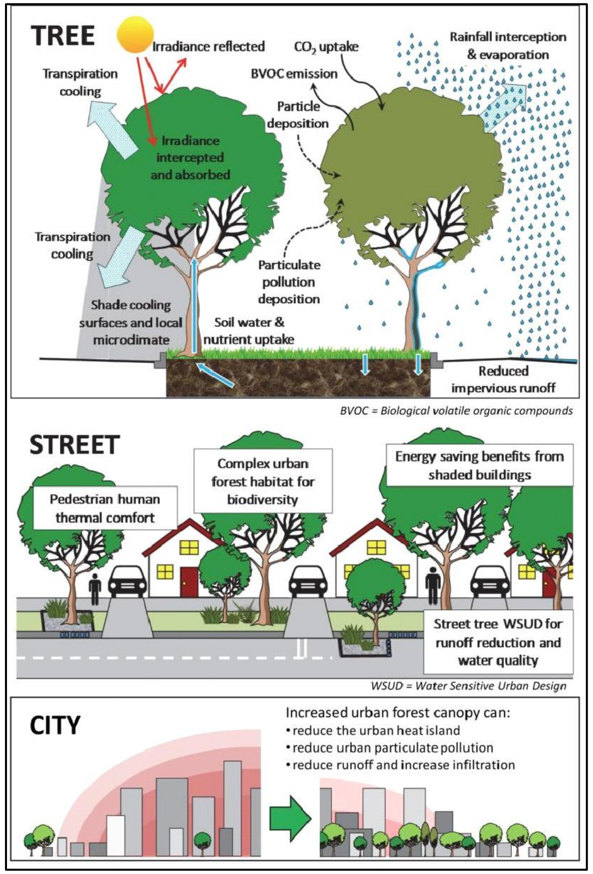
Green Urbanism is an interdisciplinary collaborative response from built environment professionals, such as, town planners, landscape architects, environmental engineers, transport planners, urban designers and architects, as well as, support professionals, such as, psychologists, sociologists and economists, in order to create more sustainable and harmonious relationships among spaces, communities and lifestyles (Source: Wikipedia).

This response has acknowledged that the rural to urban migration is creating huge pressure on existing urban centres, many of which are not coping to keep up with the provision of extensive networks of utilities, transport, housing and public facilities. A huge negative impact upon these urban centres is the growing pollution and consequential heat island which is contributing to global warming (see below).

Urban heat island effect



Tree-scapes in Green urbanism



Green Urbanism is therefore a positive response designed to mitigate urban heat islands through mass greening of sidewalks, roadways, roofs, vertical walls, additional parks and conservation areas, as shown adjacent. Green Urbanism also integrates SUDS and waterways as can be seen below in the massive project which transformed Seoul. An inherent challenge of most cities is the pollution of its stormwater and waterways. Cleaning up these waterways presents big challenges, but the concept of floating islands with wetland-type plants provides the ideal habitat for micro-organisms to populate the plant roots trailing in the water and thus clean up these waterways. This video from Biomatrix Water "living water cities" demonstrates these opportunities.

Green urbanism through restoration of waterways, Cheonggyecheon River, Seoul, Korea

3.4 Sustainable Design Integration

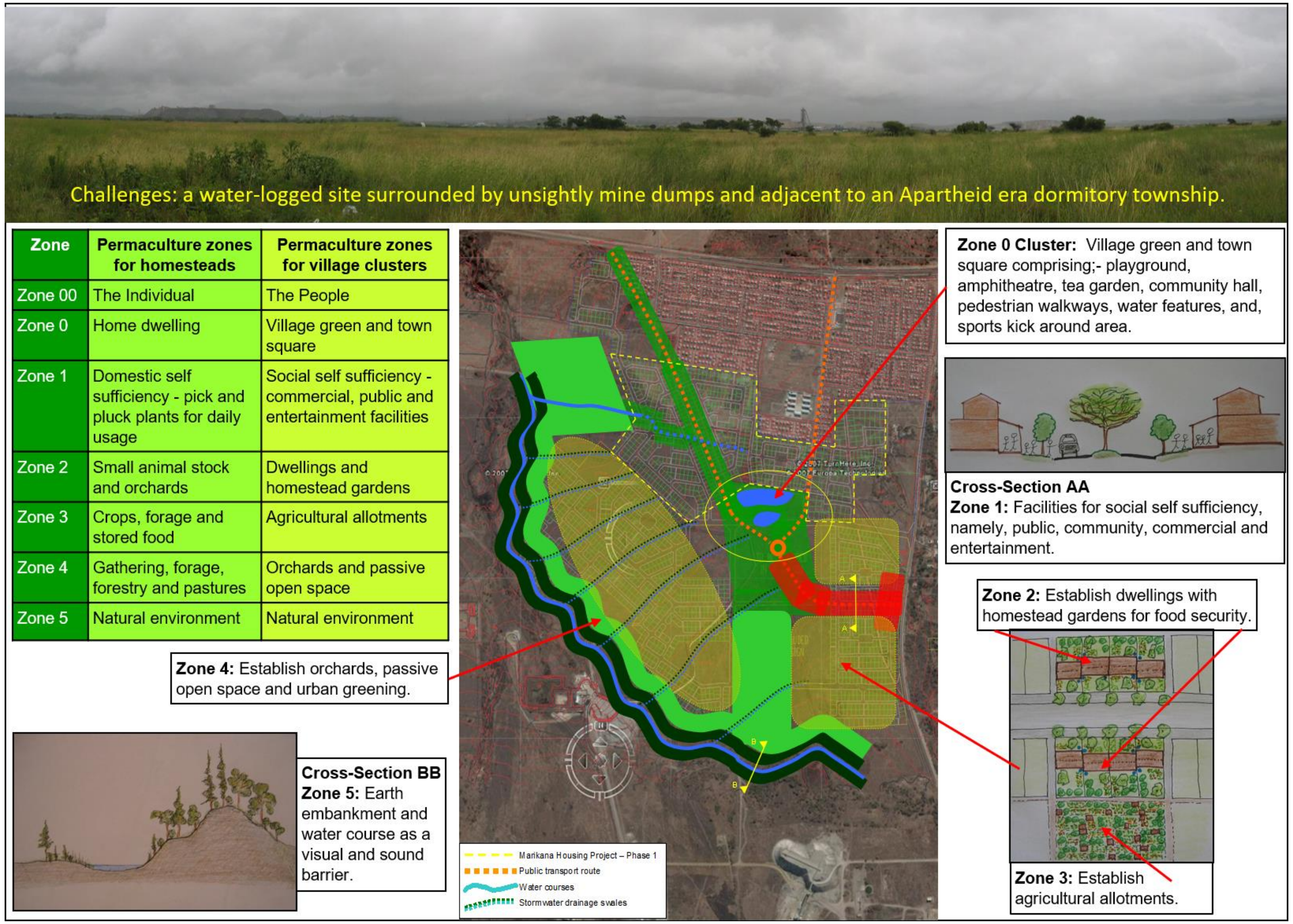
The integration of sustainable building (3-D) and spatial (2-D) strategies are now presented via some design examples that highlights the application of whole systems thinking for the built environment under the following topics;-

- Permaculture design in the built environment
- Sustainable Ecovillage Design Principles
- Retrofitting Suburbia

Permaculture design in the built environment

The Permaculture design principles also applies to the built environment. In particular, Permaculture Zones can be extended from a typical homestead across a whole village and town as shown adjacent: A Permaculture inspired town planning concept for Marikana, South Africa. In this example, Zone 5 was designed as a meandering stream (maximizing edge) to collect the water drained from the centre of a water-logged development area in such a manner that the earthworks dug out for the stream and drainage channels are used to establish an earth mound with natural vegetation, thereby screening the unsightly mine dumps (the problem is the solution). The draining of the site would make way for the other inner zones comprising passive open space (Zone 4), agricultural allotments (Zone 3), dwellings and homestead gardens (Zone 2), social self-sufficiency, commercial, public and entertainment facilities (Zone 1), and, a village green and town centre (Zone 0) for the people of this community (Zone 00). The Zone 1 area would form an activity corridor providing access and integration with an adjacent developed area.

A Permaculture inspired town planning concept for Marikana, South Africa



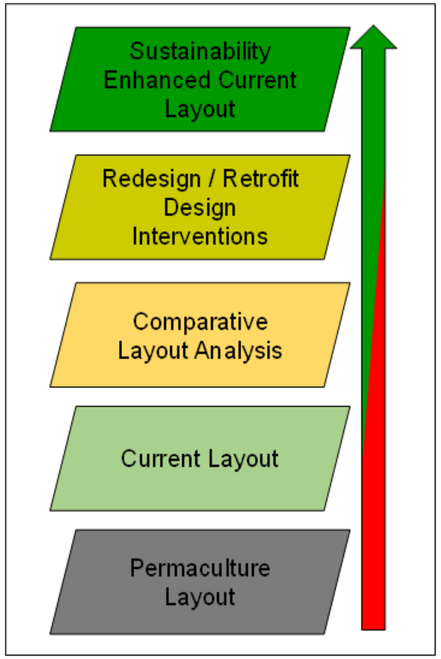
Zone	Permaculture zones for homesteads	Permaculture zones for village clusters
Zone 00	The Individual	The People
Zone 0	Home dwelling	Village green and town square
Zone 1	Domestic self sufficiency - pick and pluck plants for daily usage	Social self sufficiency - commercial, public and entertainment facilities
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

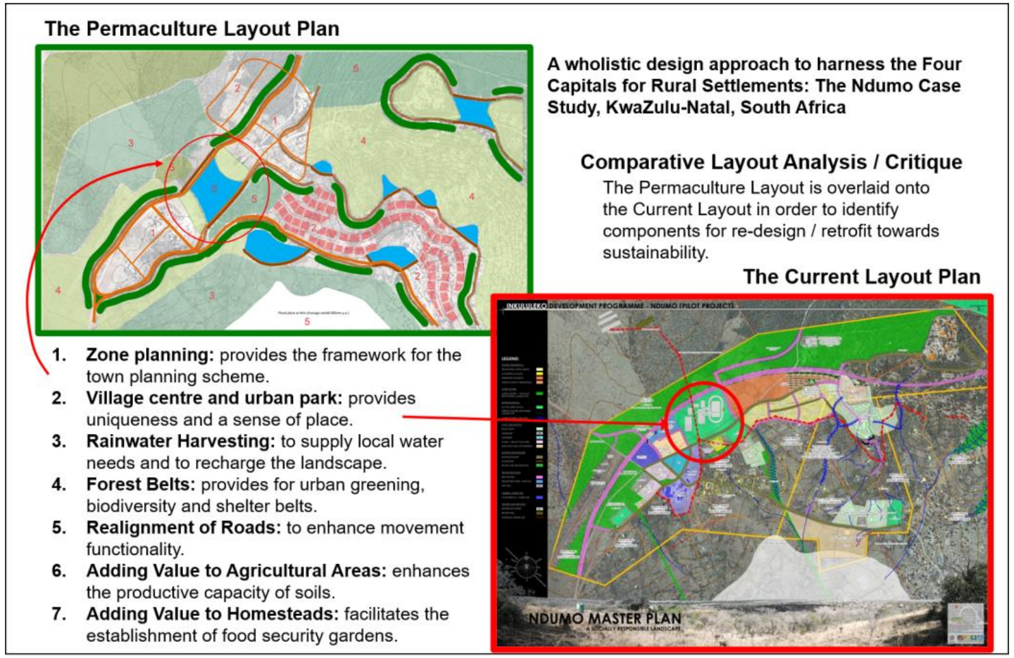
Another application of Permaculture in combination with Yeomans' Scale of Permanence (also known as Keyline Design) was used for the Ndumo case study project, which methodology is shown below. This case study was compiled in order to facilitate debate towards a more sustainable town plan, and also, to validate that sufficient water could be harvested from the landscape to supply all the town's needs instead of the more expensive planned bulk water supply from 30kms away. The debate for a more sustainable town plan was done by juxtaposing an ideal concept layout plan, as derived from Permaculture principles, against the current development reality (see adjacent illustration).

The ideal layout plan conceived a robust framework by following the Keyline design process of rainwater harvesting, access roads and forest belts, which in turn, delineated the Permaculture zones for the town development.

A closer scrutiny of this comparison was done to facilitate debate to re-align, re-design and retrofit the current reality towards a more sustainable layout plan for the overall development. Moreover, the landscape-based rainwater harvesting plan was calculated to be sufficient to meet the town's future estimated population of 2 000 homes or 12 000 people instead of relying on a 30km bulk water supply, which source was questionable.

Redesign / Retrofit methodology towards a more sustainable layout





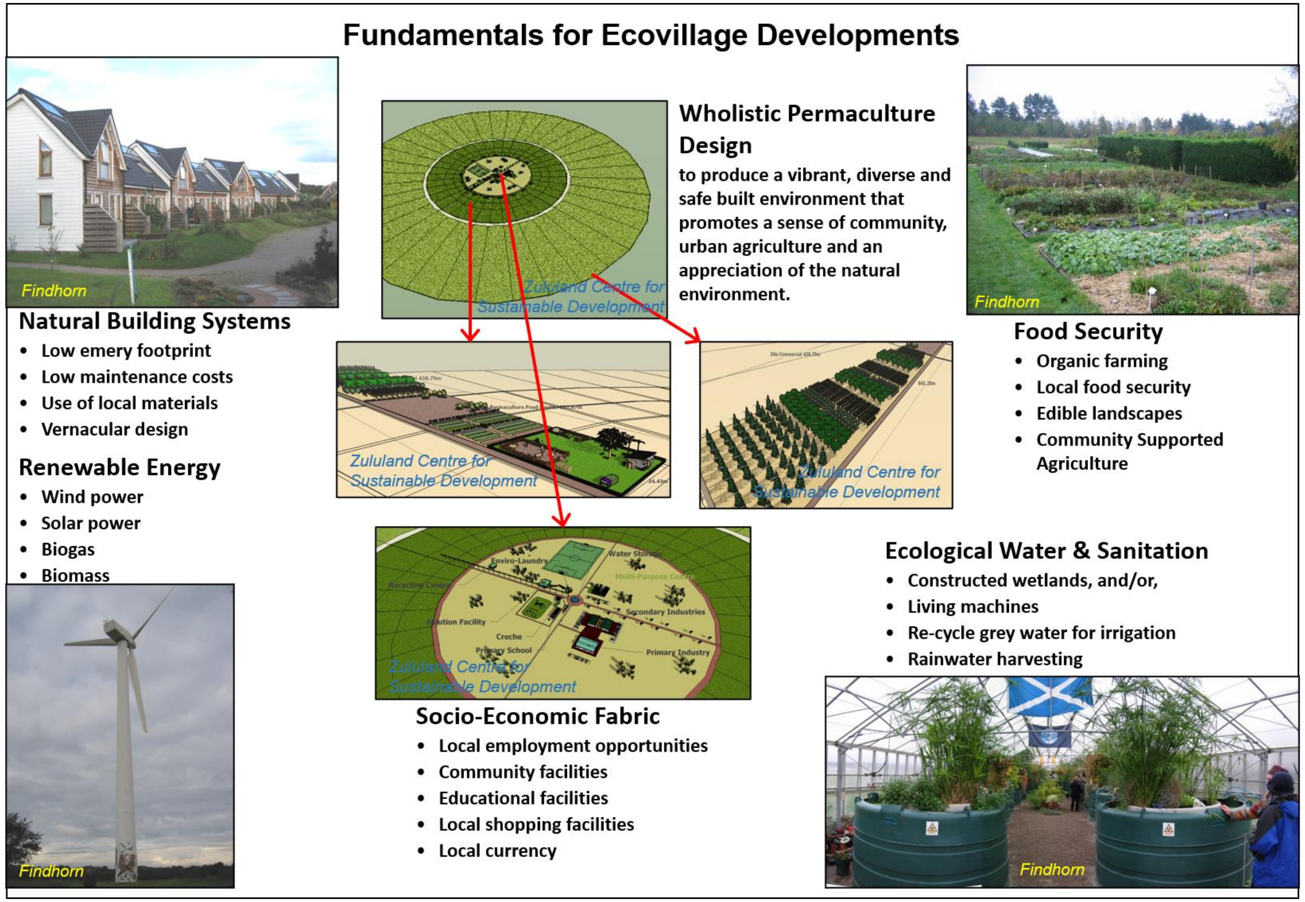
Sustainable Ecovillage Design Principles

If inhabitants of single dwellings appreciate sustainable cyclical design principles that reduce operational and maintenance requirements, then it will be easier to extend these principles outwards into an Ecovillage community. To this end, a community in formation of some 30 odd families, could well co-develop the following "green design brief" to help them evolve towards planning and establishing an Ecovillage, as illustrated below and emulated in many established Ecovillages.

- A simple shared design theme fitting into the local vernacular
- Relatively small houses, making for economy and small ecological footprint
- Passive solar space & water heating
- Bioarchitecture - cooling with landscaping and roof overhangs for shading and natural ventilation
- Using local materials where possible with low embedded energy
- Carbon neutral settlement in operations, which means no fossil fuels, or at least built to a "Gold Standard" of 4 to 6 $kgCO_2pa/m^2$
- Using Permaculture as a key design principle within the settlement
- Small scale food production and agroforestry
- Cooking and supplementary heating using biomass and/or biogas, including district heating systems
- Rainwater collection and grey water irrigation
- Local sewage treatment and treated effluent re-use, including composting toilets
- Composting of organic wastes
- Shared facilities - gardens, common house, outdoor kitchen, greenhouse, chicken tractors, laundry & bike shed
- Cohousing and land trust ownership model
- Car sharing and biodiesel production

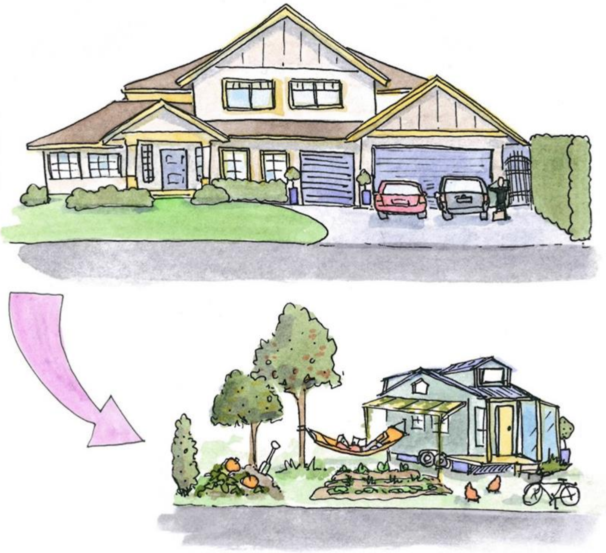
For Greenfield developments, the wholistic village layout designed according to Permaculture principles is the most important fundamental which lays out the framework for the development, failing which, the development will forever deal with retrofitting process to enhance operational sustainability.

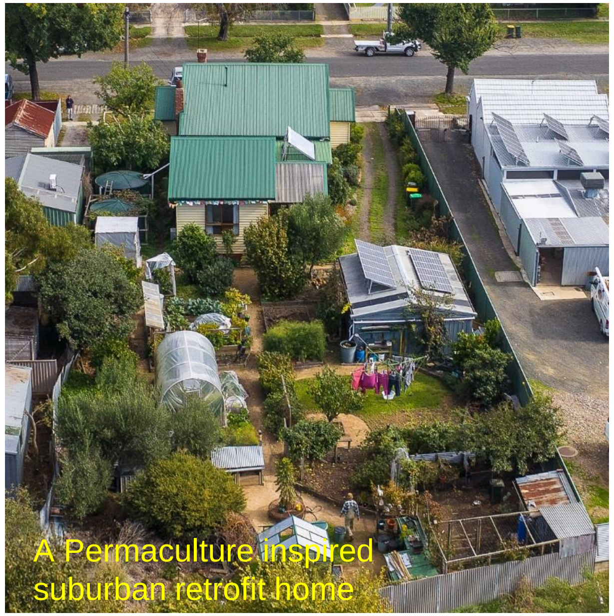
Fundamentals for Ecovillage Developments



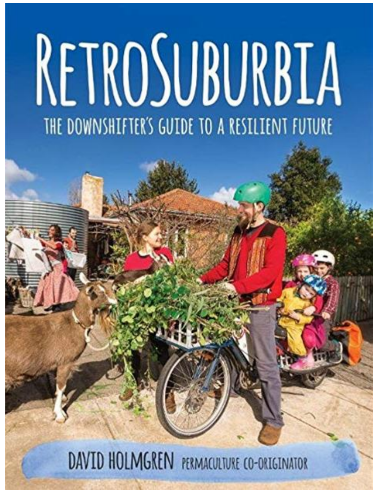
Retrofitting Suburbia

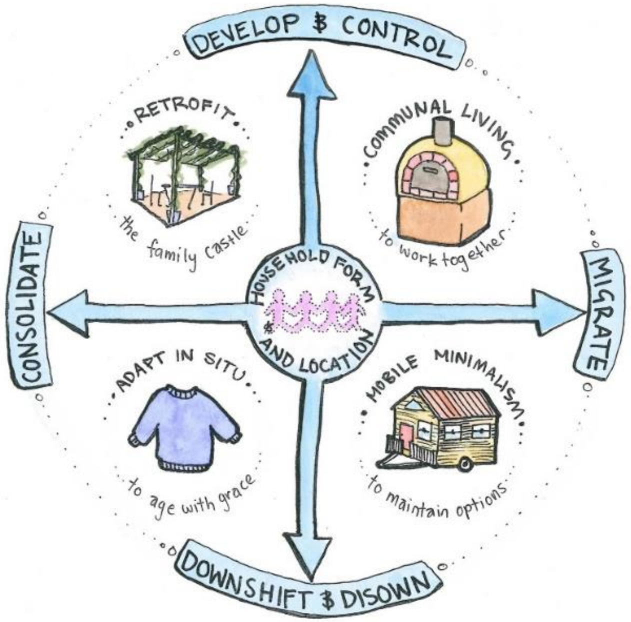
The co-founder of Permaculture, David Holmgren, has taken the Transition Movement to a very practical level in Retrofitting Suburbia (the website, book and roadshow) by demonstrating "how Australian suburbs can be transformed to become productive and resilient in an energy descent future. It focuses on what can be done by an individual at the household level (rather than community or government levels)". It shows how to live more sustainably by retrofitting one's home, establishing edible gardens, and, for communities to be more self-organised, sustainable and resilient. This is another application of how the 4-Capitals of the Natural-, Built-, Human- and Social-Capitals can be applied within the built environment, as depicted in the collage below from images of the retrofitting suburbia website. See a short video (1.45 minutes) or a longer video (32 minutes).





A Permaculture inspired suburban retrofit home





Human and Social Capitals are vital to retrofit suburbia

Source: Images from Retrofitting Suburbia

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perma module

Student Coursebook: Volume 4 – Soil, water and biogeographical regions

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Vol. 4 - Soil, water and biogeographical regions.

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1. Soil

A. SOIL COMPONENTS

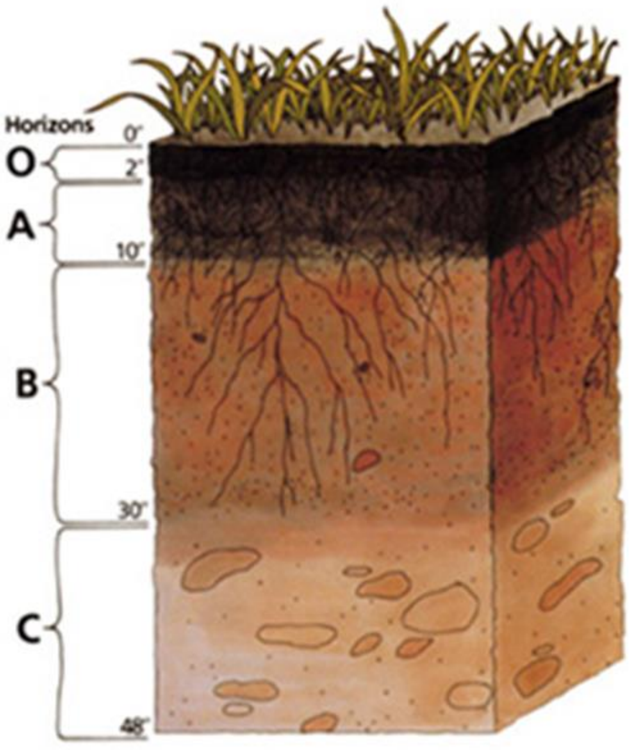
B. SOIL PROPERTIES

(1) SOIL TEXTURE

(2) SOIL PH

(3) CATION EXCHANGE CAPACITY (CEC)

A. Soil components



Soil horizons (source: Wilsonbig, Wikipedia)

Soils are dynamic and diverse natural systems, formed at the interface between rock (lithosphere), water (hydrosphere), air (atmosphere) and the living world (biosphere).

The formation of a soil is essentially driven by three main processes: the alteration of rocks and primary minerals (alteration which can be "chemical", "physical" or "biological"), the incorporation of organic matter from the living world, as well as the redistribution of these components within the soil profile. These material redistributions can also exit or enter the soil profile. This includes losses at the bottom of the profile (leaching of nutrients in solution and leaching of insoluble particles in solid form) or from the top of the profile (erosion).

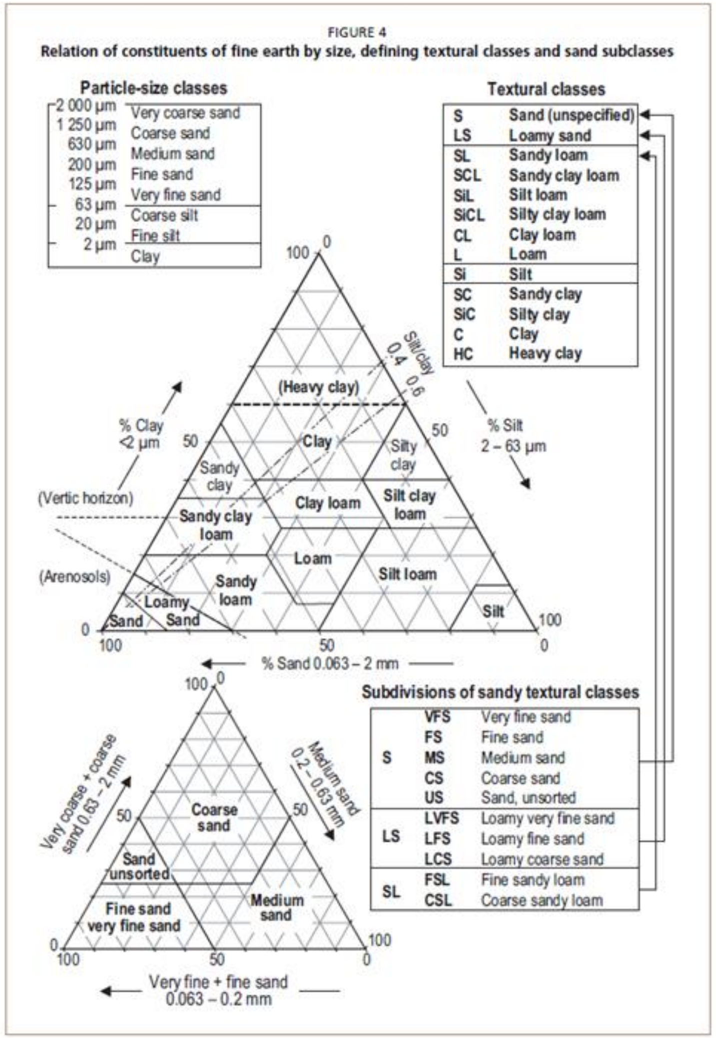
As a result, soils are made out of mineral and organic matter (more concentrated on the surface), but also of water and gas. For more information, please refer to Appendix I.

These different properties essentially depend on the 5 factors of soil formation: the topography, the climate, the parent material, the living world and the weather.

B. Soil properties

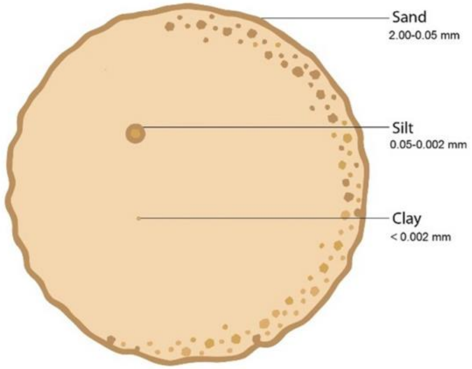
Soil texture

Once the mass proportion of at least two of these three different textural classes is established, we can define the texture of the soil studied using the textural triangle.

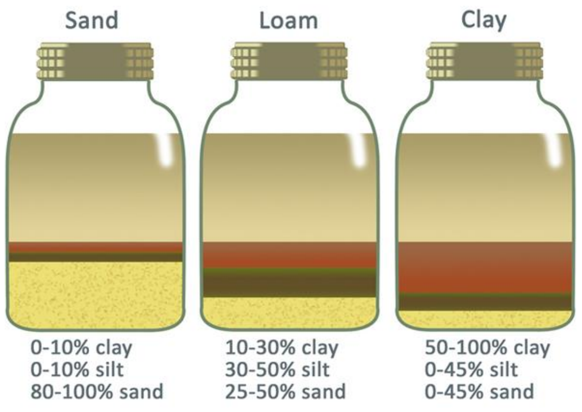


One of the main characteristics of a soil is texture. Texture is an essential parameter to take into account when studying a soil. Indeed, it will provide information both on the physical characteristics of the soil (water retention, porosity, etc. see next chapter), but also on soil fertility (see more on CEC).

Being composed mostly of mineral matter (between 90 and 100% in most cases, see chapter on organic matter), characterizing the size of these particles gives a lot of information on the soil studied. There are three different textures: sands (diameter = 2000-50 µm), silts (50-2 µm) and clays (<2µm). Beyond 2000 µm, the particle will be considered as a "coarse element". The following diagram illustrates these different textural classes:



B. Soil properties
Soil texture – Test I



Source: https://www.waternewsnetwork.com/what-kind-soil-do-you-have-take-soil-test/

Soil texture can be evaluated by leaving a few handfuls of soil in a jar filled with water. After several hours at rest, the different mineal parts of the soil should become visible by differentiation. The small rocks and heavier pieces fall at the bottom, sand fills that part as well. Above the sand layer, silt can be found. The lightest mineral particles, thus clay, is found at the top of silt. The different parts can be roughly evaluated by comparing the height of each layer.

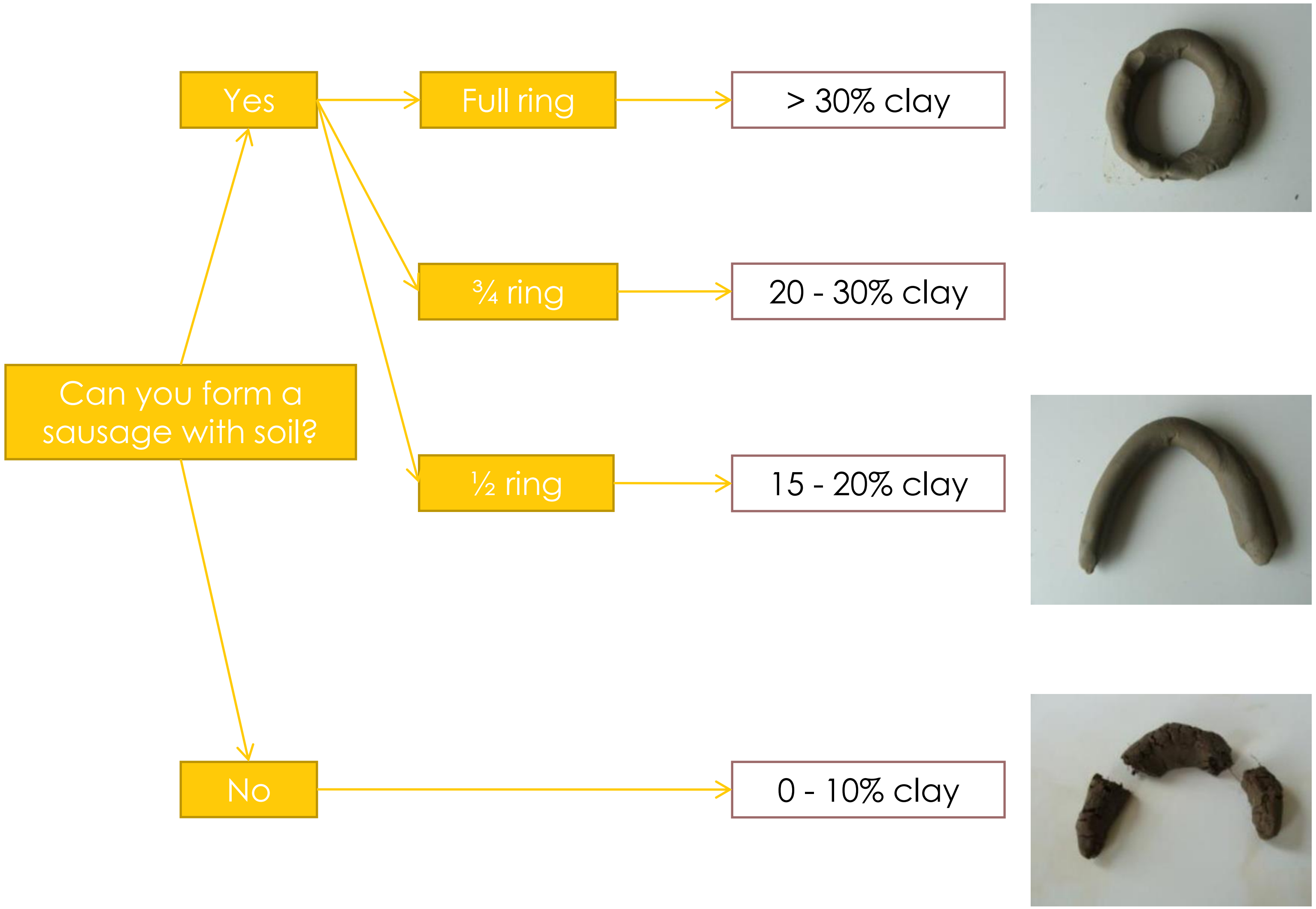
Depending on the tested soil and horizon, a dark brown layer can appear at the top of the clay layer. This dark layer is made from organic matter and gives an indication on the organic matter content of the tested soil. The water becomes turbid because of the (small but not inexistent) solubility of clay and the soluble organic compounds, if present.

B. Soil properties

Soil texture – Test II

The ring test is used to determine the clay content of a soil. The sand content (feel + sound) is then determined before deducing the silt content.

Take a soil sample in the palm of your hand. If the soil is too dry, moisten it lightly. Be careful, there should be neither too much nor too little water. If the soil is hard to moisten, one can already deduce significant clay contents (probably> 30%). If it is impossible to make a ball with the soil, sand is predominant. Then perform the ring test.



Ring test

The texture of this soil has a clay content around 20 and 30%. The dark brown surface humus layer is left out from this test.

B. Soil properties
Soil pH

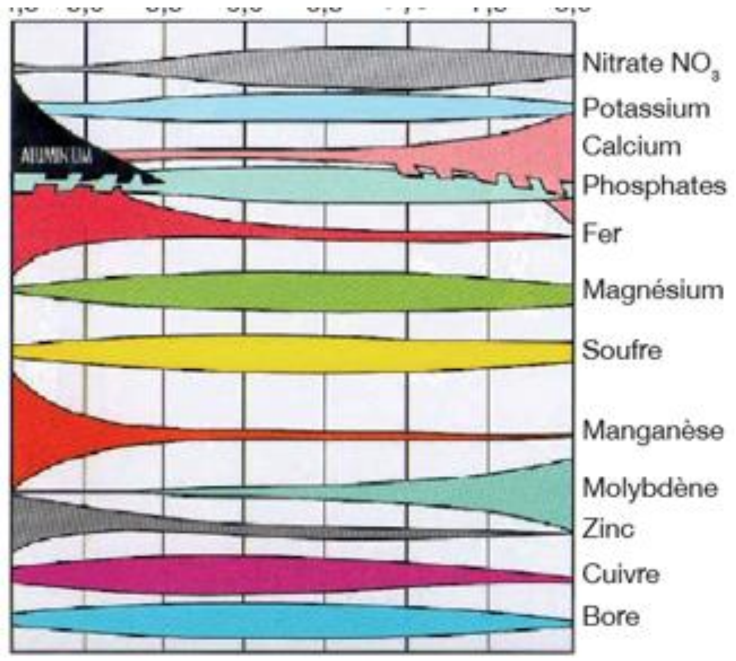


Figure 1. Schéma d'assimilabilité des éléments nutritifs par les végétaux en fonction du pH du sol — *Nutriment assimilability by plants according to soil pH* (Truog *in :* Méralle, 1998)

Soil pH is also a key parameter, because it will influence the microbial activity of soils, as well as the cation exchange capacity (see below) and the availability of nutrients for the plant. It varies from 3 to 10 but will more likely lie between 4.5 and 8.5.

Soil pH depends for a major part on its mineralogical properties. For example, a soil containing carbonate minerals (calcite) will always be alkaline (greater than 8).

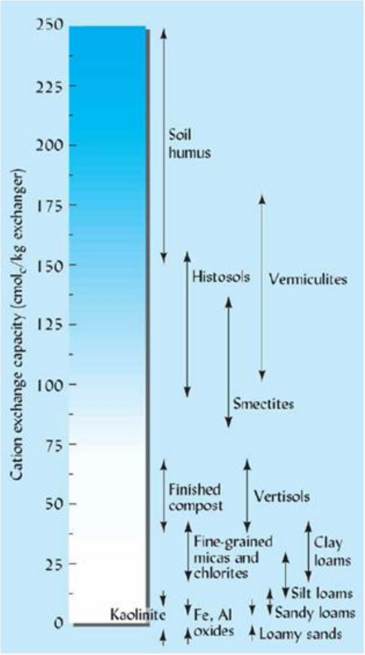
B. Soil properties
Cation Exchange Capacity

The mineral and organic constituents of soils are electrically “charged”. These charges can reveribly fix ions dissolved in the soil solution on the surface of organic and mineral consitiuents thus developing a reserve of nutrients available to the plant. These minerals are then said to be “exchangeable”. While some ions will be more strongly bound than others, other ions will be less bound and more easily retrieved or replaced.

The set of negative charges of a soil is called “cation exchange capacity (CEC)” (in moles of positive charge per kilogram of soil), reflecting the capacity of a soil to adsorb / desorb cations, and therefore nutrients for the plant (Ca2+, Mg2+, K+, Na+, etc.). The different types of charges arise as follows:

- Charges on organic matter: these charges depend on the pH of the soil, so we speak of “variable charges”.
- Charges on mineral particles: some minerals are "intrinsically" negatively charged: this is called permanent charge.

Given these varying parameters, the soils of the world are characterized by very different CECs (see figure above). From these values, it becomes clear that organic matter (as “soil humus”) makes it possible to achieve very high CECs, more than the phyllosilicate content. We therefore understand the importance of the content of organic matter (OM) for soil fertility.



Soil Order	Average CEC ($cmol_c/kg$)
Alfisols	15 ± 11
Andisols	31 ± 18
Aridisols	18 ± 11
Entisols	20 ± 14
Histosols	140 ± 30
Inceptisols	21 ± 16
Mollisols	24 ± 12
Oxisols	8 ± 6
Spodosols	27 ± 30
Ultisols	9 ± 6
Vertisols	50 ± 17

From: Sposito (2003) *The Chemistry of Soils*

CEC ranges of different soils (sources: Brady et al. 2008; Sposito, 2003)

2. Water

Soil structure & hydrodynamics

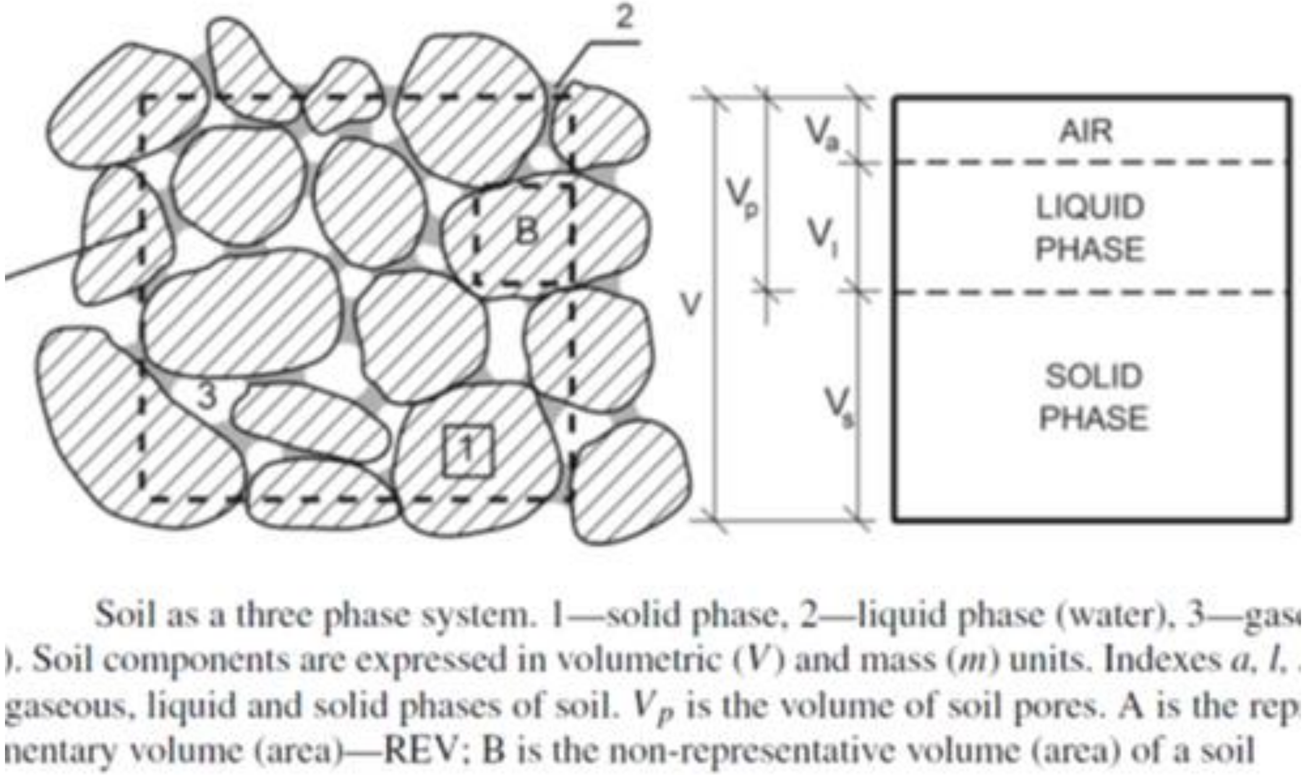
- Soil structure
- Water retention in soils
- Hydraulic conductivity
- Water infiltration

Evapotranspiration

A. Soil structure and hydrodynamic properties
Soil structure

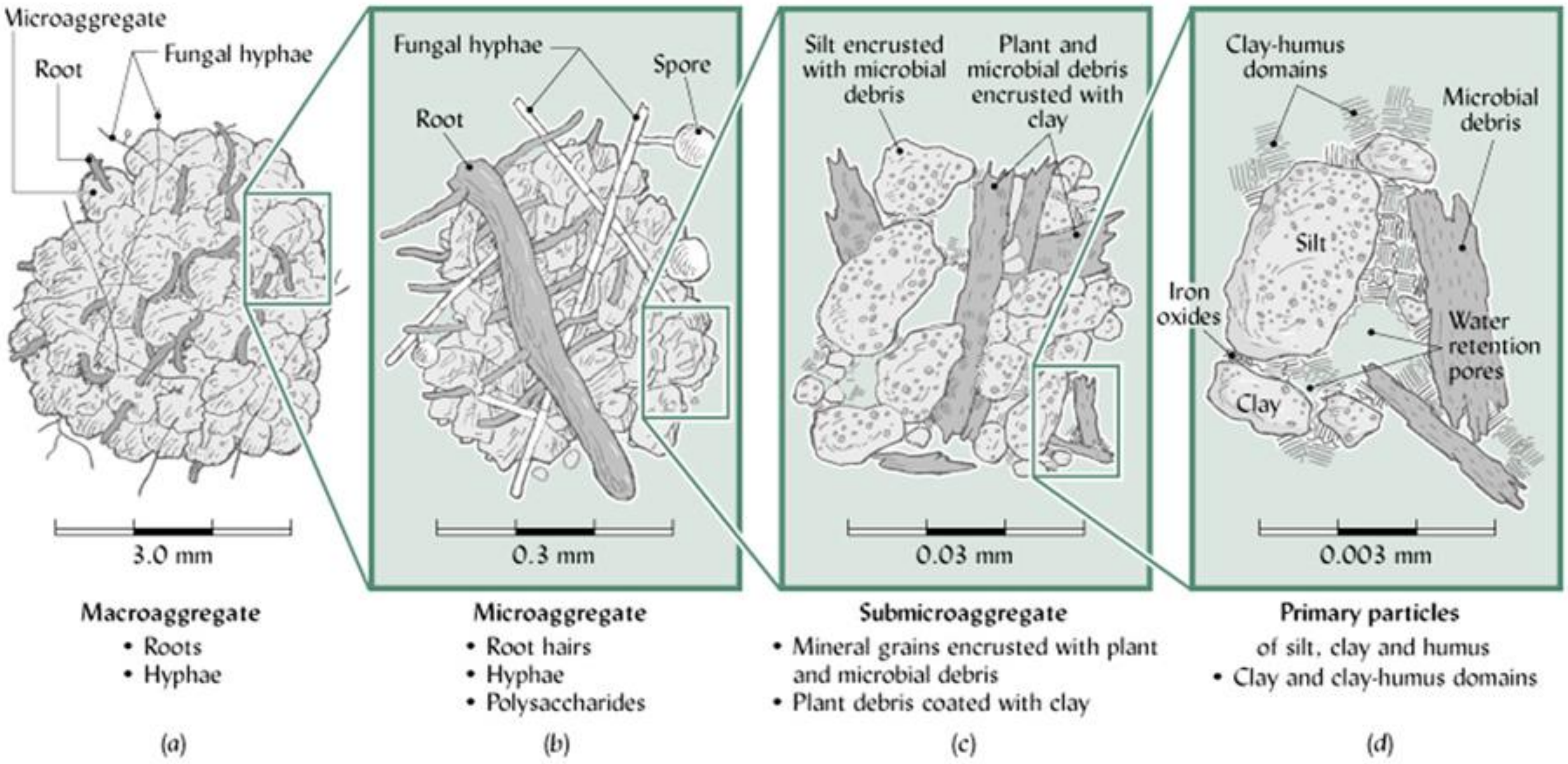
Soils lie at the intersection between three phases, made up of solid, mineral and organic matter and a porosity that can channel and store fluids (liquid: soil solution and gas: air).

The structure of a soil will of course depend on its texture. For example, a soil containing >90% sand will have an almost non-existent structure. The particles will have a small specific surface (the ratio surface/volume is low because of the relatively large size of sand), which minimizes the potentials to interact with other particles and water. Interactions will be almost non-existent. Organic matter content will also be key to the structure and aggregation of a soil. This relationship is explained more in details in Appendix II.



Soil as a three- phase system (source: Novak et al. 2019)

The soil structure is the arrangement between the different mineral particles (sands, silts and clays), as well as with organic particles. These particles aggregate together under the action of soil biology, acting on different scales, and form structural units. For example, in the diagram below, we see in image (d) that a silt particle, a clay particle and ”microbial debris" are linked to each other. Particles the size of clays (iron oxides, and very small “organo-mineral associations”) also “cement” these particles together. This pattern may be repeated several times to obtain units, called aggregates (a, b, c).



Detailed aggregate structure (Brady et al. 2008)

A. Soil structure and hydrodynamic properties

Water retention in soils

Soil moisture varies depending on the soil properties such as the structure and the hydraulic conductivity, weather, plant uptake, evaporation conditions. Soil structure, in the large sense, can be described at different spatial scales: from atoms to landscapes, from nanostructure to macrostructure, as illustrated in the following picture.

At these different scales, the empty spaces formed by the structure (within the aggregates, between the aggregates, in the cracks, the galleries, etc.) are the place of storage and circulation of water and air.

Water retention in soils is determined by the different forces acting on it. On the one hand, the force of gravity, present everywhere, but on the other hand there are attractive forces with a very small radius of action, and capillary forces.

Thus, water movement in soil is influenced by the varying porosity:

- Around the soil particles or between the layers, which constitute them, the water will be strongly bound to the soil (hygroscopic water, not available to plants because the water is too strongly bound).
- In medium-sized pores, water will be retained by capillary action. Capillarity compensating for the effect of gravity, water is sometimes called "suspended". It can be collected by plants.
- In the largest pores, the capillarity is weak and no longer makes it possible to counter gravity. The water in these pores will tend to move down the profile or laterally, depending on the slope. We talk about drainage porosity.

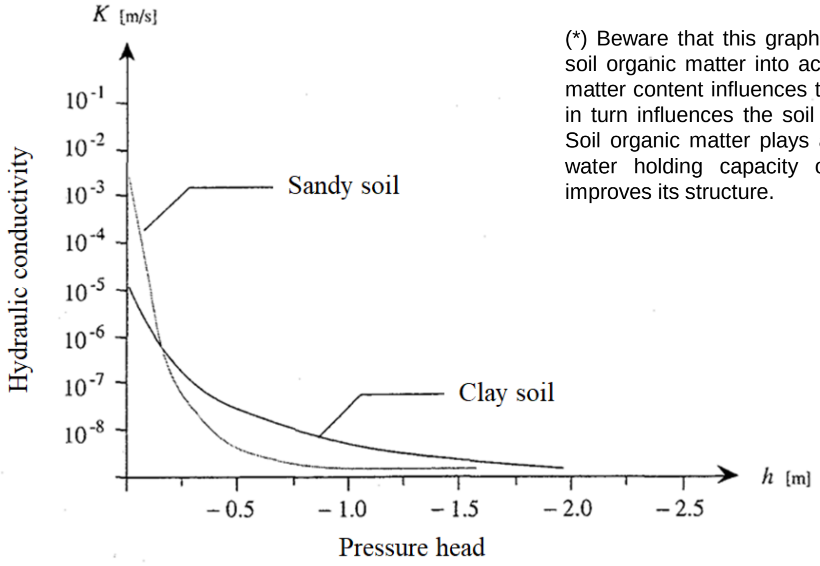
A. Soil structure and hydrodynamic properties

Hydraulic conductivity

The second major property of soils defined by porosity is their hydraulic conductivity. The hydraulic conductivity (K (h)) [length per time] varies according to the water content of the soil and it expresses the capacity of the soil to allow water to pass through it under the effect of a pressure gradient. At constant water content, water will only percolate through liquid channels. Likewise, air will flow only through empty channels. At saturation, there are only liquid channels, no air can pass through. In a dried-out state, on the right, only gaseous channels, no water can pass through. Therefore, the hydraulic conductivity will be higher when the water content is close to saturation.

The hydraulic conductivity curve of the soil is therefore an intrinsic property of the soil, which is also largely influenced by its texture and structure. The above graph illustrates that macro-porosity is the place where water moves within the soil, as the water infiltrates much faster in a sandy soil than in a clay soil at saturation. In sandy soils, air pores are big, therefore they will be prone to block the water from flow. Thus, the conductivity diminishes very quickly, as shown on the graph above.

At saturation, the hydraulic conductivity is at its maximum. The following graph gives a first approach based on the texture (*).



(*) Beware that this graph does not take the soil organic matter into account. Soil organic matter content influences the structure, which in turn influences the soil water conductivity. Soil organic matter plays a major role in the water holding capacity of a soil since it improves its structure.

Hydraulic conductivity curve: The hydraulic conductivity is related to the pressure head and to the soil texture (source: adapted from Musy et al. 1991)

A. Soil structure and hydrodynamic properties

Water infiltration

The infiltration of water through soil, following rain, sprinkling or irrigation will depend on its retention and conductivity properties, its initial water content and possibly the submergence height for flood irrigation. The surface condition may play an additional role, for example when a slaking crust has formed or if the extremely dry soil has developed hydrophobicity.

In the following video, infiltration tests in three soils with contrasted textures illustrate the role of this soil characteristic: https://www.youtube.com/watch?v=ego2FkuQwxc&t=215s

A partial preview of the video is given in the following picture. Infiltration tests taking into account aggregation, inclusion of residues or even the presence of bypasses within the profile illustrate the impact of agricultural practices.

The video also shows the effect of obstacles and of discontinuities on the infiltration.

B. Evapotranspiration

The concept of evapotranspiration englobes the water losses on the aerial side of the plant and is of utmost importance in order to evaluate the plant's water needs. If a plant lacks water, it experiences a “hydric stress”. An occasional hydric stress will not be detrimental to the plant, but a prolonged hydric stress can weaken the plant, impeding photosynthesis and altering nutrient uptake, sometimes leading to death. **Evapotranspiration, as the name shows, combines the transpiration factor and the evaporation factors.**

On the one side, the plant aerial parts (leaves, stem, etc.) lose water through the stomata (micro-openings on the plant surface) by a process called **transpiration**. The plant takes up water and nutrients through the roots, and then the major part of the taken up water is lost through transpiration. This process drives the nutrient uptake of the plant.

On the other side, the **evaporation** part comes from the water loss from the ground surface. When water is heated, it turns into vapor and is retrieved by the ambient air. The crop canopy, the shading of the soil surface, the soil surface moisture, and the irrigation frequency are factors, which influence the evaporation rate of soil water.

Evapotranspiration is the combination of those two processes. Its units are expressed in [mm/day]. The main factors which influence evapotranspiration are the temperature patterns, the sunlight radiation reaching the ground, the air moisture content, the wind speed, and the type of crop. Other factors will also influence this water loss. The evapotranspiration is usually higher in the warm and sunny seasons than in the cold and darker seasons.

Evapotranspiration can be evaluated from different equations, giving the reference evapotranspiration. Other factors related to the crop type and the cropping practices, coming from experimental measurements, are then multiplied with this reference evapotranspiration to obtain the real evapotranspiration

More detailed information about evapotranspiration and the way of computing it can be found on the FAO page about evapotranspiration, referenced as Allen et al. (1998).

3. Fertility

Nutrient cycling

- Nitrogen
- Phosphorus
- Potassium
- Calcium and Magnesium

Soil Organic matter

Soil biology and the soil food web

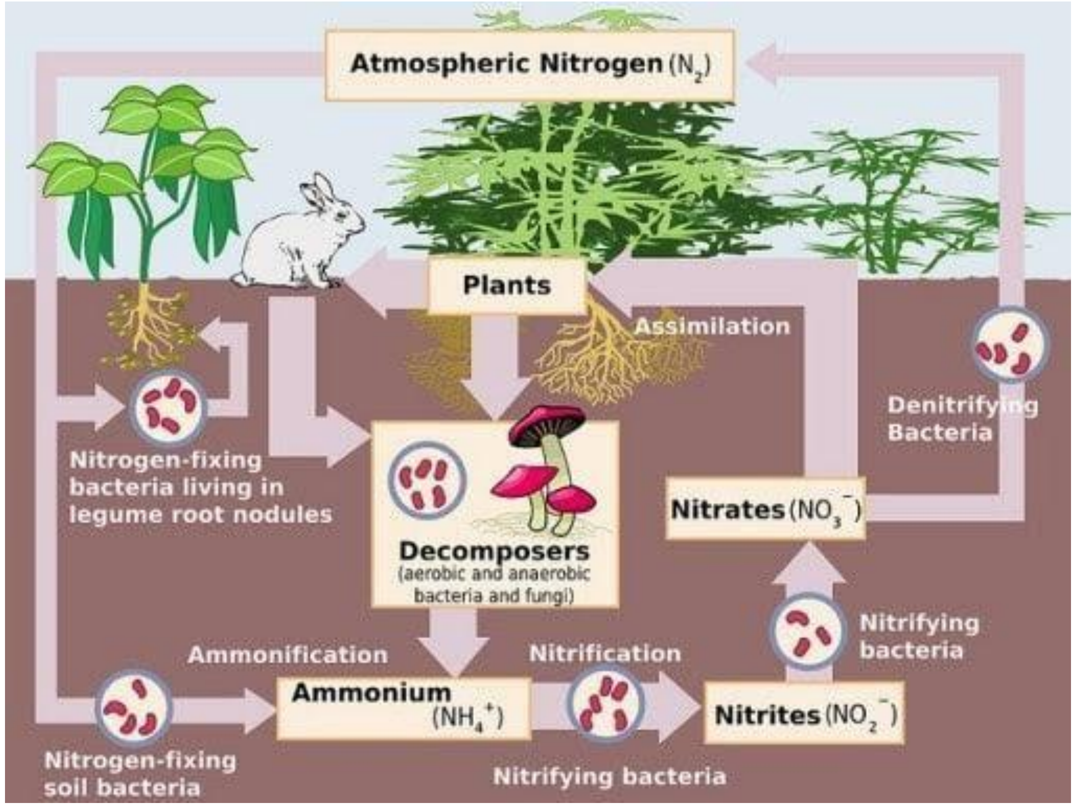
- Introduction and plant-microbe symbiosis examples
- Soil organisms
- Soil food web

A. Nutrient cycling

Nitrogen

Nitrogen is a key element in plant nutrition. It is one of the main constituents of amino acids, proteins and nucleic acids that make up DNA and RNA. Limiting nitrogen will therefore reduce plant growth. The symptoms of nitrogen deficiency generally include a light green/yellow coloring of the leaves, which will synthesize less chlorophyll (chlorosis). According to a recent study, the primary productivity of around 20% of natural terrestrial ecosystems is limited by the lack of nitrogen (Du et al. 2020 - Nature Geoscience). A plant can absorb nitrogen from the soil solution in two distinct forms: nitrate (NO3-) or ammonium (NH4+).

Nitrogen can be found in minerals (Holloway, 2002; Bourzac, 2018) like many nutrients, but an important nitrogen source is air: before plants can absorb and use it, it must pass from the atmosphere, where there is gas (dinitrogen N2), to the soil. This process is achieved by certain bacteria (some of which live in symbiosis with legumes), or by industrial processes. Another way to add nitrogen to the soil is to add mineral fertilizers or organic fertilizers that have already accumulated nitrogen in their tissues. A series of decomposers (from the large herbivores to the bacteria) will then be responsible for making it available to the plant. The nitrogen "soil-plant" cycle is presented below:

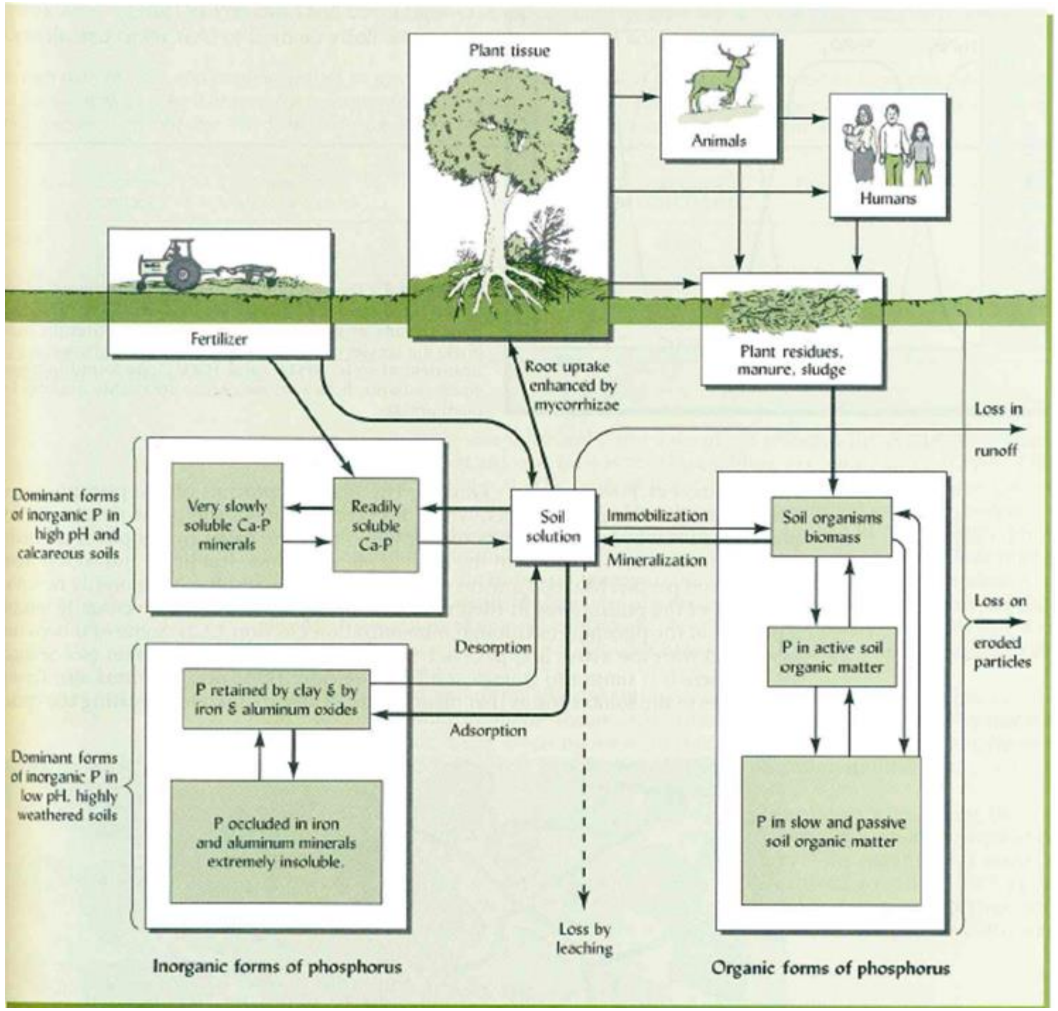


Nitrogen cycling (source: wikipedia)

A. Nutrient cycling
Phosphorus

Phosphorus is also a very important element in plant nutrition. For example, it is estimated that the primary productivity of about 40% of natural terrestrial ecosystems would be limited by the lack of phosphorus (Du et al. 2020 - Nature Geoscience). Unlike nitrogen, phosphorus comes mainly from rocks, from the mineral world. The total stock of P in a soil will therefore be very dependent on its “intrinsic” properties (especially the properties of the parent material here in this case, but also its age and more generally its degree of deterioration, see chapter on soil constituents). It is converted into organic phosphorus once it has been assimilated into living tissue. Mycorrhizae greatly contribute to the assimilation of P by the plant.

The following diagram shows the soil-plant cycle of phosphorus.

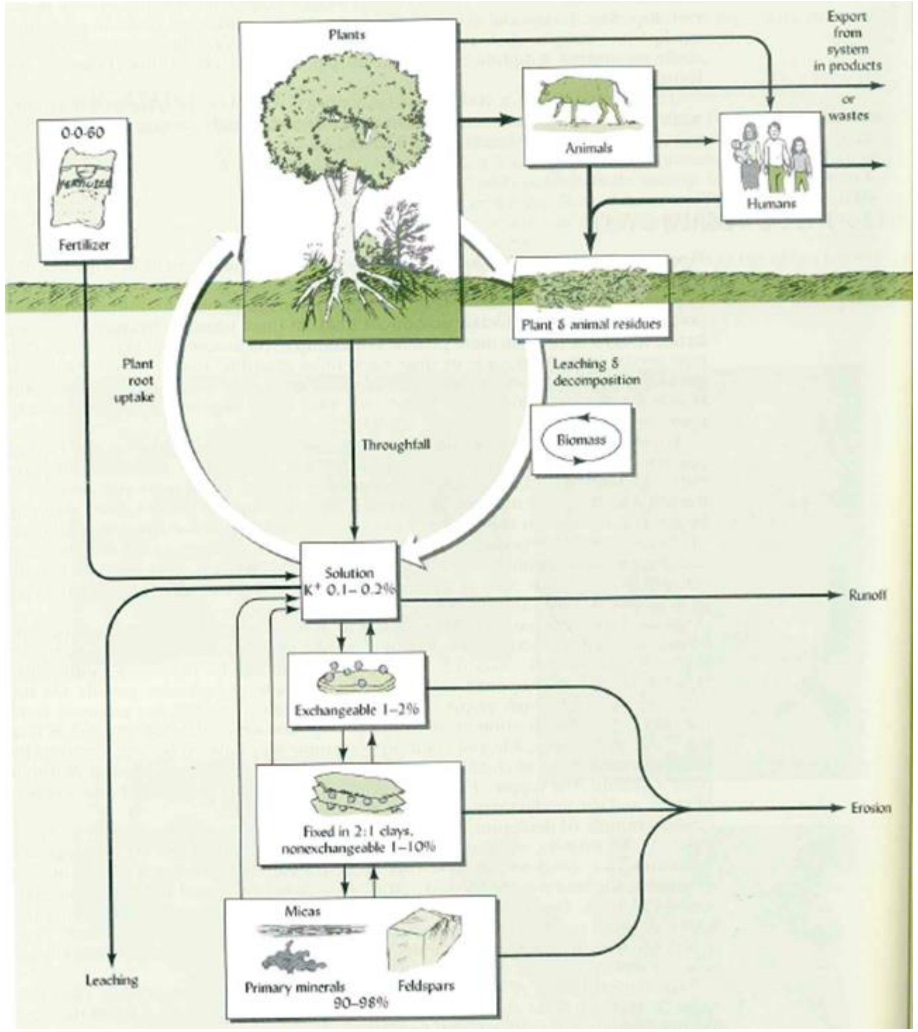


Phosphorus cycling (source: Brady et al. 2008)

A. Nutrient cycling
Potassium

After nitrogen and phosphorus, potassium is the element most likely to limit primary productivity. This is why conventional fertilizers are composed of NPK (Nitrogen - Phosphorus - Potassium). Like phosphorus, the primary source of potassium in a soil-plant system is parent material (so stocks are very dependent on the "intrinsic" properties of the soil). But just as for the other nutrients from rocks (Ca, Mg, P, etc.), only a small percentage of the total amount present in the soil is available to the plant. Soil biology can contribute in increasing the amount of nutrients made available to plants in the soil solution.

This cycle is illustrated in the following diagram.



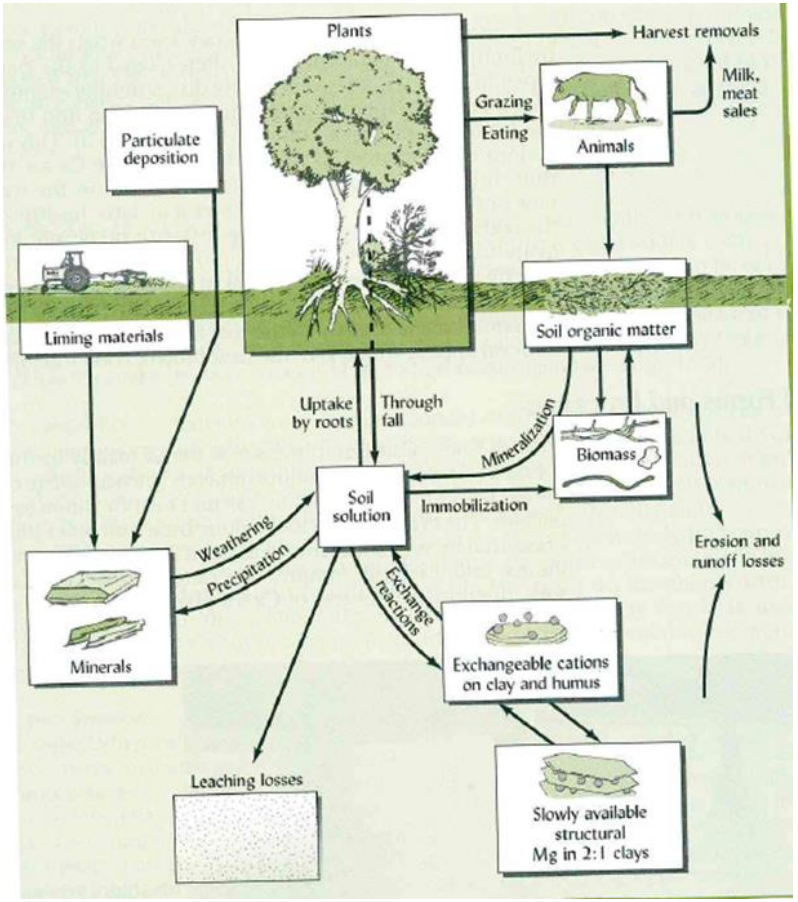
Potassium cycling (source: Brady et al. 2008)

A. Nutrient cycling

Calcium and Magnesium

Calcium and magnesium are also essential elements. Calcium participates among other things in the strengthening of cell walls and the growth of young roots. Magnesium is involved, among other things, in the activation of many enzymes and in the synthesis of proteins and sugars. Like P and K, they come primarily from parent material (carbonate minerals, but also feldspars). Their total stock will therefore be very dependent on the intrinsic properties of the soil (especially the parent material in this case). One of the differences with NPK is that they are often brought to the soil by liming. The function of this practice is generally not to provide Ca and Mg, but to increase the pH by providing a strong base (see chapter The soil components). This strong base is often associated with Ca and/or Mg, they are added to the soil through this.

The following diagram represents the soil-plant cycle of Ca and Mg.



Calcium and Magnesium cycling (source: Brady et al. 2008)

B. Soil organic matter

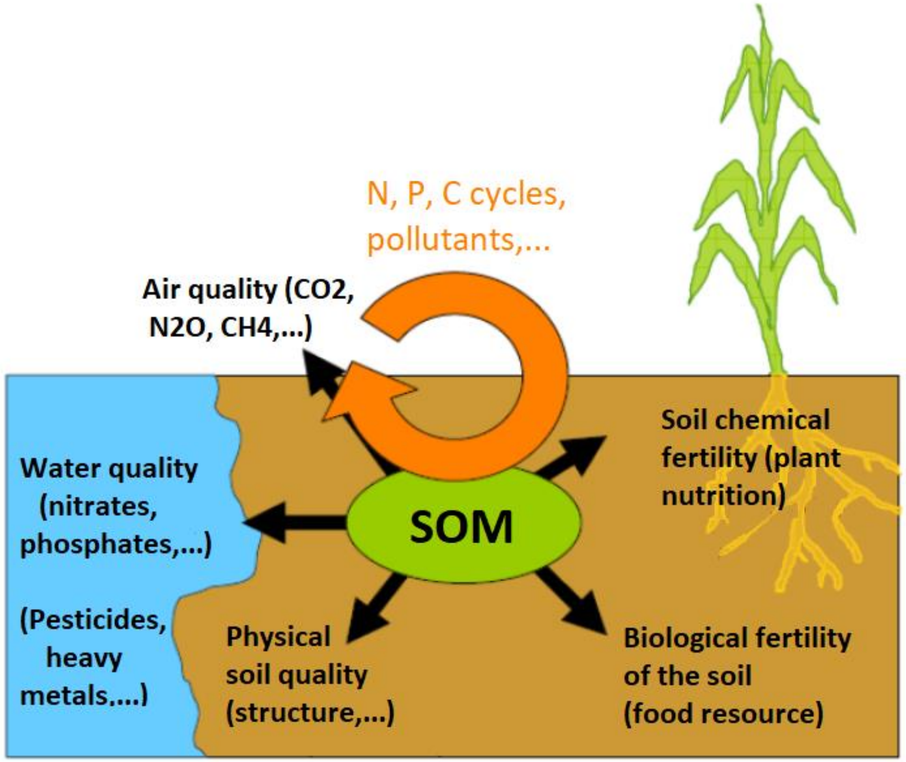
Organic matter is decomposed organic material (such as dead organisms, dead plant matter, and such) stored in the form of very stable, long and complex molecules. These molecules are not soluble and have a very high carbon content (about half of its mass consists of carbon atoms). The nutrients stored in these molecules are for the most not available to plants, but some living soil organisms can access them. Other sources of carbon in soil are living organisms and plant exudates.

Globally, soils contain more carbon than vegetation and the atmosphere altogether. Therefore, soil are crucial on the global carbon cycle as they can act as carbon sink to mitigate global warming.

In a soil profile, the accumulation of organic carbon takes place at the surface and is identifiable by a horizon that is darker than the deeper horizons, which are dominated by the mineral world.

Some of the other benefits of soil organic matter are: improved air and water quality, nutrient cycling, fertility, increased CEC,…

The OM being reactive, it allows a good retention of pollutants, in particular pesticides and metals, before they are transferred to the water table.



Soil organic matter (SOM) is the main source of energy for all heterotrophic organics living in the soil. Providing OM therefore increases the “biological” fertility of the soil: mineralization of this OM to release nutrients, aeration of the soil, formation of organo-mineral associations by mixing the organic and mineral horizons (bioturbation), release of nutrients via mineral alteration i.e. “bioweathering”, etc.

The soil OM is reactive (see first chapter). Increasing its content in soils will increase soil aggregation and impact its retention and conductivity properties. However, the dynamics of the structure's evolution are still poorly understood.

The following table lists the main causes of decrease/increase in organic carbon content in soils. Major loss causes are bare soil and inappropriate agricultural practices.

In addition to environmental factors (climate, type of vegetation and ecosystem), certain factors inherent to the types of soil are very important to explain their content of OM, and their capacity to “conserve” this carbon. For example, soils with a finer texture (clays, silts) may store more carbon than soils with a coarser texture (the possibility of forming organo-mineral associations is more important if the texture is fine because the mineral surfaces are more reactive and their charged surfaces allow the mechanisms of adsorption of dissolved organic molecules. These organo-mineral associations contribute to the stabilization of OM and thus to decrease their turnover within the grounds, as demonstrated by the positive relation between texture and content in matters organic (any other environmental parameter considered to be constant)

Factors promoting gains	*Factors promoting losses*
Green manures or cover crops	Erosion
Conservation tillage	Intensive tillage
Return of plant residues	Whole plant removal
Low temperatures and shading	High temperatures and exposure to sun
Controlled grazing	Overgrazing
High soil moisture	Low soil moisture
Surface mulches	Fire
Application of compost and manures	Application of only inorganic materials
Appropriate nitrogen levels	Excessive mineral nitrogen
High plant productivity	Low plant productivity
High plant root:shoot ratio	Low plant root:shoot ratio

Factors affecting the balance between gain and losses of organic matter in soils (source: Brady et al. 2008)

C. Soil microbiology and the soil food web

Introduction and plant-microbe symbiosis examples

The soil biome consists of different types of organisms interacting with every part of soil. This includes the other soil organisms and higher vertebrates, the organic material, the mineral part of the soil, water, and air. The soil organisms play a role in the macro and micro-structure of the soil.

The vast majority of green plants are able to produce different types of sugars through the direct use of sunlight in a process called photosynthesis. This process uses the sun energy to combine carbon dioxide and water molecules into a linear chain of carbon, oxygen and hydrogen atoms called carbohydrates. By this process, plants fix gaseous carbon (CO2) from the air into the products of photosynthesis. These products are then redistributed into the plant to be transformed into amino acids and other useful molecules or to be excreted by the roots into the soil as “exudates”. (Schulze et al. 2019)

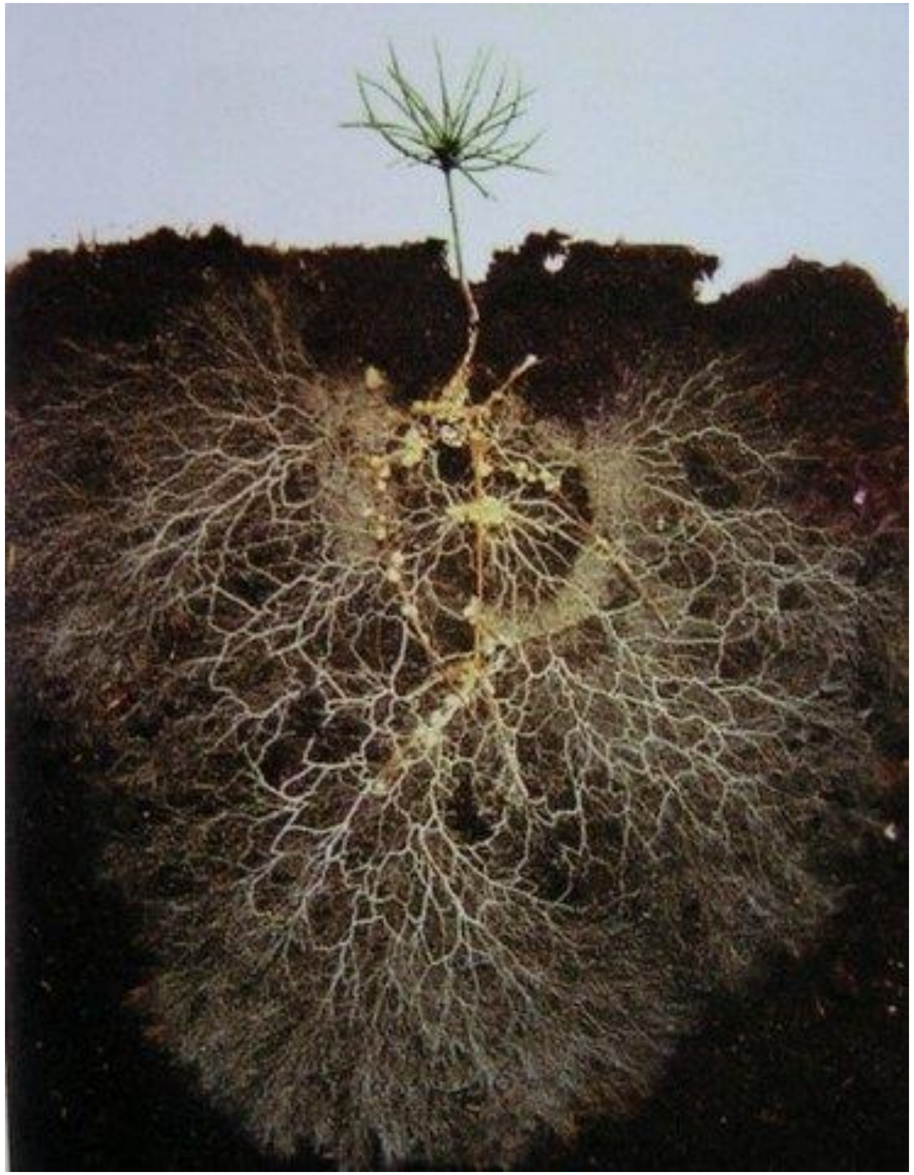
Since most microbes are unable to perform photosynthesis, the rhizosphere biome (the life in the root zone) benefits from those exudates, shaping different kinds of relationships between the plant and the surrounding microorganisms. For example, some mycorrhizal fungi can permeate the root membrane and form arbuscules in the root. These arbuscules are the privileged exchange sites for carbohydrates, water and nutrient exchange. Fungal hyphae permeate the soil more easily and therefore enable the plant to access a larger range of nutrient sources. This is illustrated on the following picture. Fungi also possess enzymes that the plant does not have. (Schulze et al. 2019)

Another remarkable example is the process of rhizophagy: Microbes (bacteria or fungi) growing on the exudate root zones enter the root tip cells. In the root, nutrients are extracted from the bacteria by the plant, benefitting the plant. As the microbe exits the root cell, it promotes the extension of the root tip. (White, 2018)

It has been recently discovered that symbiosis could also be trilateral. Just as the plants can welcome endophytic bacteria in the rhizophagy process, the hyphae (fungal filaments) of some fungi are capable of hosting nitrogen-fixing bacteria while working in a mutualistic relationship with plants. (Paul, 2020)

One "last but not least" example is the symbiotic relationship between plants from the Fabaceae family, but not exclusively (Santi, 2013), with specific nitrogen-fixing bacteria, or rhizobia. The bacterium colonizes the root cells, and then multiplies as it receives the highly energetic carbohydrates from the plant. This multiplication forms noticeable nodules on the plant roots. When the nodule is developed enough, the nitrogen-fixing gene of the bacterium is expressed to produce nitrogenase. The gaseous nitrogen (N2) from the air is then converted and absorbed by the nodule and transmitted to the plant. (Basu 2020)

Various other symbiotic relationships between plants and the soil biome can occur. These relationships have been shown to improve plant disease resistance, drought resistance, plant growth and nutrient uptake by plants. However, note that these relationships will not take place if the organism is absent from the soil or in dormant stage without favourable conditions to quit this stage. Also, some of these symbiotic microbes need specific conditions (oxygen content, humidity, undisturbed soil, etc.) to colonize the plant root. If the conditions are not ensured, for example in the case of a compacted soil, the beneficial microbe will be out-competed by other microbes more adapted to these conditions.



The mycorrhizal hyphae (white threads) lengthens the root system (brown) of the plant and improves its nutrient absorption (Source: Rachael Kowaleski)

C. Soil microbiology and the soil food web

Soil organisms

The soil organisms include bacteria, fungi, protozoa, nematodes, earthworms, micro-arthropods, gastropods and so on. These organisms interact in a trophic chain called the soil food web. Further details on each organism are given in Appendix III.

1. **Bacteria:** The decomposing bacteria play an important role in nutrient cycling as they need a certain amount of N to be able to consume C from decomposing material. If the C:N ratio of the organic material is too small, the excess N from the organic material is mineralized and made available to plants. On the contrary, if there is a deficit in N in the organic material, nitrogen from the soil solution will be immobilized by the bacteria to be able to consume the C. Symbiotic bacteria form mutualistic relationships with the plant which allows the plant to grow on nitrogen captured from the air.

2. **Fungi:** Fungal hyphae (fungal filaments) have a diameter ranging from 3 to 10 micrometers, which is smaller than root hairs, enabling fungi to reach nutrients located in narrow spaces. In contrast with bacteria, most fungi grow more efficiently on low nitrogen substrates and dominate soils which are less disturbed. (Paul, 2014) Fungi play also a role in soil structuration though their hyphal network that binds micro-aggregates together to form macro-aggregates. Mycorrhizal fungi form symbiotic relationships with the plant, which gets more nutrients, show a higher plant growth rate and a better disease resistance. Saprophytic fungi are decomposers: they feed on dead organic material. Their secondary metabolites are very stable and complex organic structures with a high carbon content.

3. **Protozoa:** Protozoa are single-celled, with a size ranging from 5 to 500µm. Protozoa are the main predators of bacteria, regulating their population, but they also feed on other protozoa, soil organic matter and occasionally fungi, helping regulate the pathogen population as well.

4. **Nematodes:** Nematodes are small worms with a typical diameter of 50 µm and length of 1mm. Parasitic nematodes (such as Root-feeding nematodes) are widely known, but there are also many beneficial nematode species contributing to nutrient cycling such as fungal and bacterial feeding nematodes, and predatory nematodes.

5. **Earthworms:** Earthworms are found in temperate soils and in tropical soils. They consume dead organic material or sometimes-mineral material and are crucial to nutrient recycling. Earthworm casts improve soil structure. Different types of earthworm live in different soil depths.

C. Soil microbiology and the soil food web

Soil food web

In the soil food web, the two primary carbon sources come from the litter (dead organic material) and from the root zone (exudates). These sources are consumed by the second trophic level of soil organisms, which are then consumed by successively higher trophic levels. In terms of ecological stoichiometry, each organism has a specific carbon to nitrogen (C:N) ratio, which is the number of carbon atoms it holds for one atom of nitrogen.

The bacteria have a very low C:N ratio, ranging from 3,5:1 to 7:1, young fungi from 10:1 to 15:1 (Paul, 2014) while protozoa have a C:N ratio of approximately 30:1 and nematodes around 100:1. Micro-arthropods have a C:N ratio amounting to several 100s to 1. Note that those C:N ratios are valid for organisms on an empty stomach and are only averaged indicators: this ratio can differ between species and depends on the growth stage of the organism. Very old fungi have a very wide C:N ratio because fungi store carbon in their body during their entire life. For example, some old white-rot fungi have been found to have a C:N ratio of 2000:1. Fungal predators only attack their growing tips, which are richer in nutrients and thus have a much smaller C:N ratio. The allocation of nitrogen to the growing tips happens through a process of translocation within the fungal hypha (Lange, 2012).

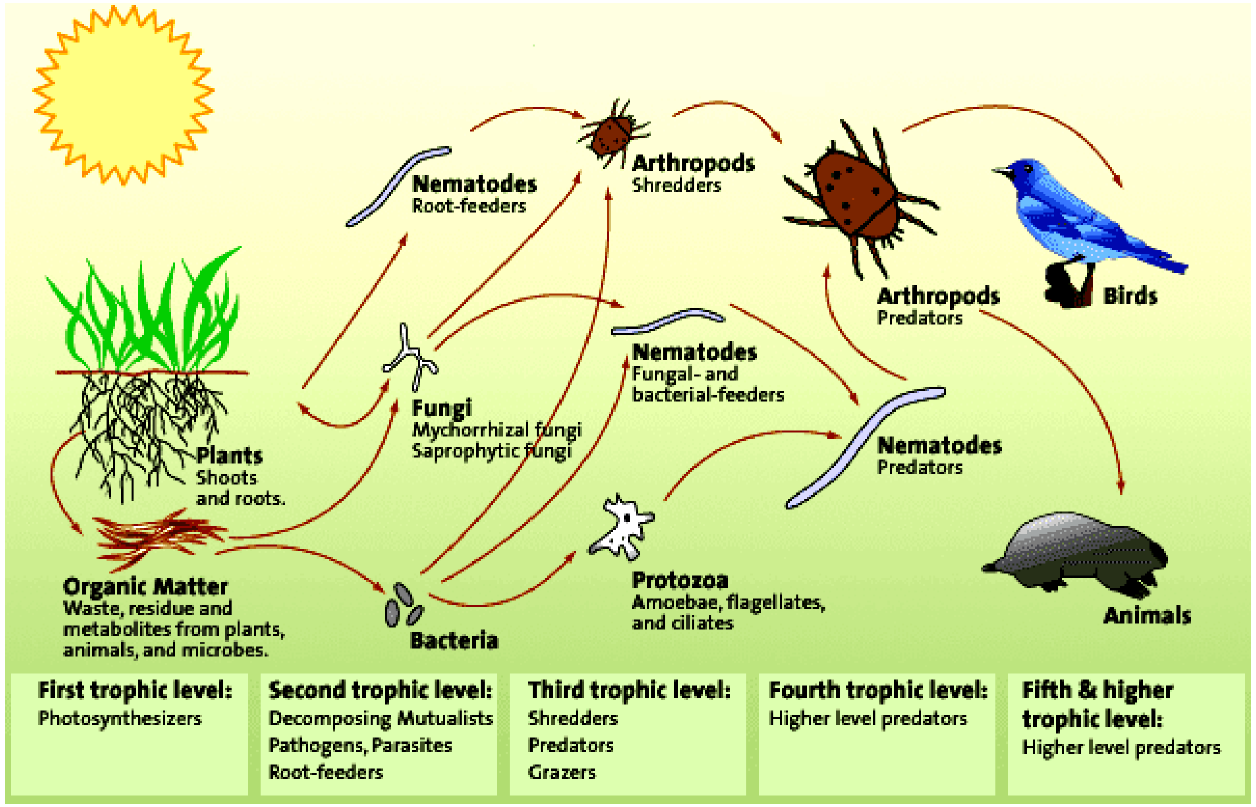
In many cases, the C:N ratio is higher in predator than in prey. Therefore, each predator, after eating a prey, has nitrogen excess. It then releases nitrogen under a mineral form, that is, a plant available form in order to re-equilibrate its own C:N ratio. This is also the case for other nutrients. As the root zone is filled with bacteria and fungi benefitting from the root exudates, this predation takes place close to the roots, therefore the plant root is able to absorb the released nutrients (Hartel, 2005; Smith, 2011).

The soil food web comprises all those strophic stages. These predatory mechanisms allow nutrients to be constantly mineralized from the (living and dead) organic pools of nutrients and to be quickly consumed by the plant or by organisms (De Ruiter, 1993). Therefore, the pool of nutrients in mineral form remains small while being constantly replenished by the consumption of prey by predators.

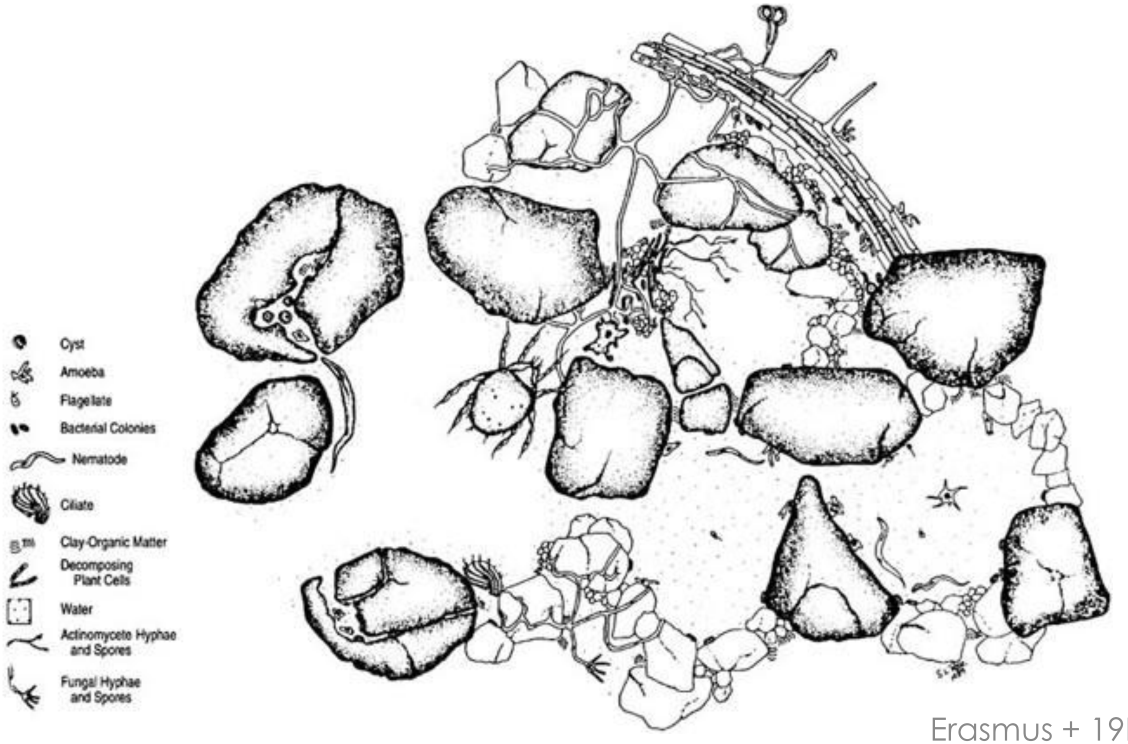
The soil food web functions like all trophic webs. If one trophic level is emptied, it will be unbalanced and the functions of the soil food web will not be fulfilled: some populations can then grow excessively while others can starve to death or go dormant.

In a soil with a fully functional soil food web, beneficial organisms develop on and occupy the root surface, making it more difficult for pests and pathogens to reach the vegetal tissue. The beneficial organisms also develop on the aerial parts of the plant, acting as a protective layer as well. (Finkel, 2017)

The soil food web also plays a role in water cleaning and soil bioremediation.



An illustration of the soil food web and its trophic levels (source: Abdelnabby, H. (2006))



Example of a soil organisation around soil micro- and macro- aggregates and plant roots. Note that the empty gaps are filled with air and the dotted zones around and between the aggregates are filled with water.
(source: Soil biology and ecology, (Rygiewicz et al. 1997))

4. Biogeographical regions

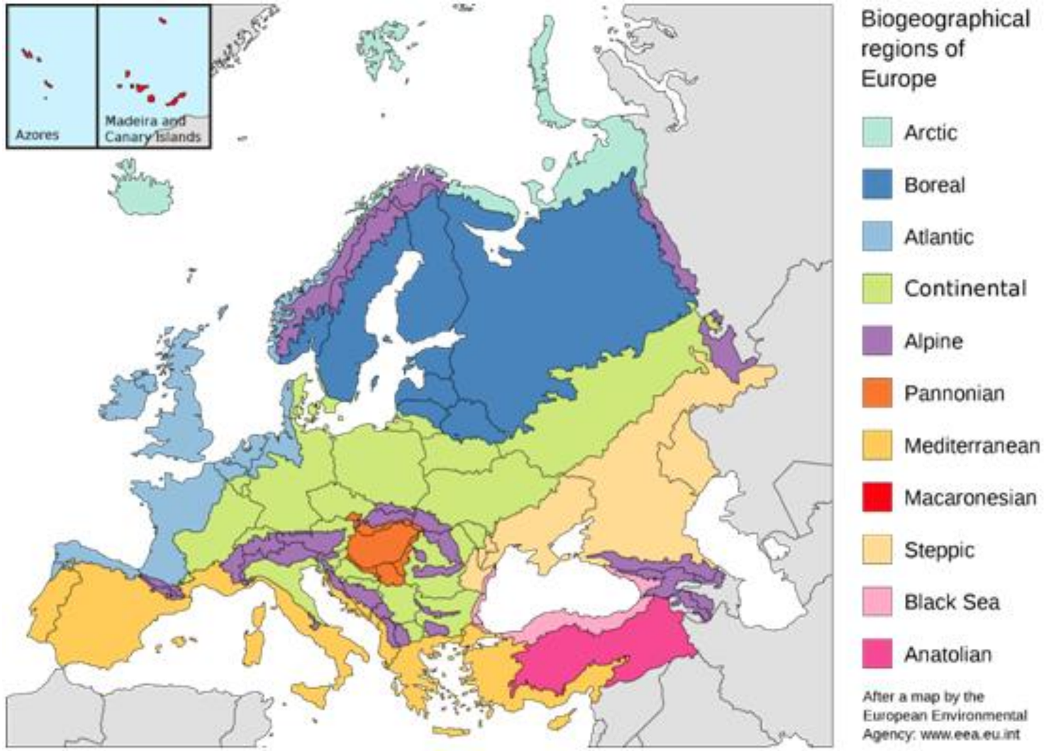
- Introduction
- The Mediterranean region
- The Continental region

Biogeographical regions
A. Introduction

Biogeographical regions describe the distribution of plant and animal organisms on the surface of the earth, i.e. in ecosystems. It includes as basic branches zoogeography (areas inhabited by animals), phytogeography (vegetation areas and floors), and ecology that studies the relationship between organisms and the environment and corology (arealography) which delimits the distribution areas for different taxa (families, species, etc.).

In Europe there are eleven bioregions (Figure 1), from an agronomic point of view, bioregions can be a tool for crop zoning. Fauna and flora are bio-indicators and sources of ecosystem services that can exist in various forms (protection of cultivated plants, quality of the environment, tourism potential, etc.).

Two examples of biogeographical regions are described below.



Biogeographical regions of Europe (source: Júlio Reis, 2020, Wikipedia)

Biogeographical regions

B. The Mediterranean region

Soils in the region vary, but limestone is widespread and is the parent material for many local soil types, especially in the central part (Italy and the Balkan Peninsula). Soils generally have a low humus content (organic matter). Due to periods of dry climate and topography with exposed slopes, there is a constant risk of erosion in more than half of the region. The average annual rainfall ranges from 600 to 1,200 mm / year, but can be up to 350 or even 100 mm. Most species in the region will occasionally suffer from a water shortage. The period of water shortage varies, usually between at least two months in the western Mediterranean and five to six months in the east. The flora of the entire Mediterranean basin in a broad sense includes over 25,000 species of flowering plants, making it the third richest in the world. Over 30 Mediterranean plants are considered to have disappeared in the last century.

Agriculture, including grasslands, occupies about 40% of the region. There are large areas, intensely used in the plains of Spain, Italy and other countries, but other parts are characterized by a small-scale mosaic structure, with gardens and orchards, being surrounded by open forests, shrubs and meadows. Vineyards, olives and fruit trees: woody species from Mediterranean agriculture - are very important in Mediterranean agricultural production. Olives, native fruit trees and oak trees appear in both wild and cultivated forms. FAO considers the Mediterranean area as one of the most important centres of origin for important crops worldwide, covering many cereals, leguminous plants, vegetables, fodder plants, fruit trees and nuts, as well as medicinal, aromatic and ornamental plants.

Coastal wetlands (deltas and lagoons) in the region support a large number of birds during migration, wintering or breeding. They are of major importance for wintering European ducks. The Mediterranean region also has a great variety of fauna. Compared to other European biogeographic regions, the region has the highest number of amphibians, reptiles and mammals.

The region is home to 134 species of mammals (not including Turkey and Cyprus), 57 species of amphibians, 89 species of reptiles and 317 species of nesting birds. The Mediterranean is the richest biogeographic region of Europe in invertebrates: 75% of the total fauna of European insects is found in this area. The Mediterranean basin is one of the richest areas of biodiversity in the world and is considered an important point in the world in terms of species. Some of the regions have a very high endemism.

Biogeographical regions

C. The Continental region

The soils have a north-south gradation. As the surplus of humidity decreases to the south-east, the leaching becomes less intense and the true podzolite soils give way to the ash-brown and less acidic forest soils, which have a much higher organic content and higher natural fertility.

Much of the most fertile soil in the region was developed on the loess, a homogeneous, fine-grained soil, influenced in the south by glacial and fluvio-glacial deposits. This type of soil depends on the climatic conditions, as well as the geological nature of the substrate. Chernozem or black soil, for example, has developed under particularly favourable conditions, producing high natural fertility, which combines low acidity and high humus content.

The climate in the region can be defined as truly continental in the east, where there are strong contrasts in seasonal temperatures, with generally hot summers and cold winters.

Winter temperatures are constantly rising from east to west. The average temperature in January is -15 ° C at the foot of the Ural Mountains, -3 ° C in Warsaw and 0.6 ° C in Strasbourg. Winter temperatures do not vary as much between north and south. The continental biogeographic region has some of the most productive ecosystems on the continent.

It is the transition zone on the N - S axis between the boreal coniferous region dominated by the forest and the open steppe region. In the EU part of the region, 149 types of habitats of Community importance are identified in the EU Habitats Directive (Annex I), of which 46 are of priority interest. Forests cover about 27% of the region. The climatic conditions and the soils are in many places best suited for deciduous forests, with different species predominating depending on the geographical location. The diversity of plant life in grasslands is associated with a wide variety of animals, especially insects, including butterflies, spiders, bees and flies.

Annual plants can include about 4,800 species of indigenous vascular plants. Trees and shrubs include up to 80 indigenous species. The number of endemic plant species in the region is limited. In Germany, for example, there are only 32 endemic species and subspecies concentrated in a few areas with special ecological conditions. The composition of the animal species reflects the intermediate nature of the continental region between the boreal and Mediterranean regions. There are at least 578 vertebrate species, not including fish, 125 mammal species, and there are around 30,000 known insect species.

APPENDICES

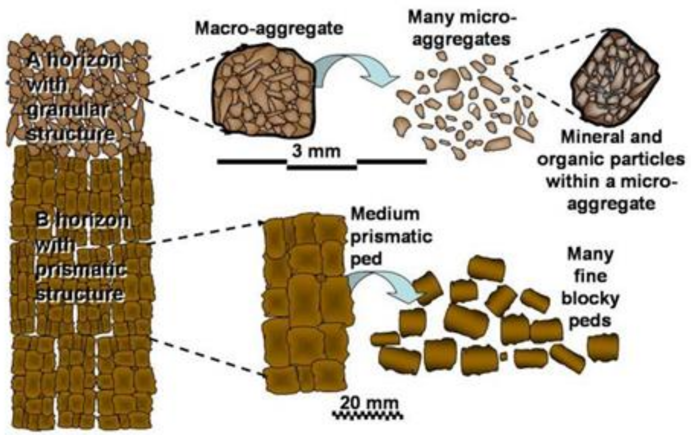
Appendix I – the soil components

	Solid components		Liquid components (soil solution)	Gaseous components (soil atmosphere)
	Mineral	Organic		
Origins	Physical desegregation and biochemical alteration of rocks	Decomposition of living organisms	Rainfall, water table, runoff	Outside air, decaying matter, respiration
Classification criteria	Size (grain) Quality (mineralogy)	State (alive, dead), Chemical quality (original, transformed)	Origin (weather, water table) Physical state (hydric potential) Chemical quality	Origin (air, organisms) Chemical quality
Categories	According to the grain size •skeleton (>2mm) •fine earth (<2mm) According to the mineralogy •Quartz •Silicated minerals •Carbonated minerals	•Living organisms •Dead organisms •Inherited organic material: cellulose, lignin, resins •Humified organic material: fulvic and humic acids, humins	•water •dissolved substances: carbohydrates, alcohols, mineral and organic acids, cations and anions	•air gas (N_2, O_2, CO_2) •Gas produced by the respiration and decay of organisms: CO_2, H_2, CH_4, NH_3

Appendix II – Horizons aggregation

Soils lie at the intersection between three phases, made up of solid, mineral and organic matter and a porosity that can channel and store fluids (liquid: soil solution and gas: air). The characterization of the solid phase of the soil relates to its texture (distribution of particle size), its mineralogy and its structure.

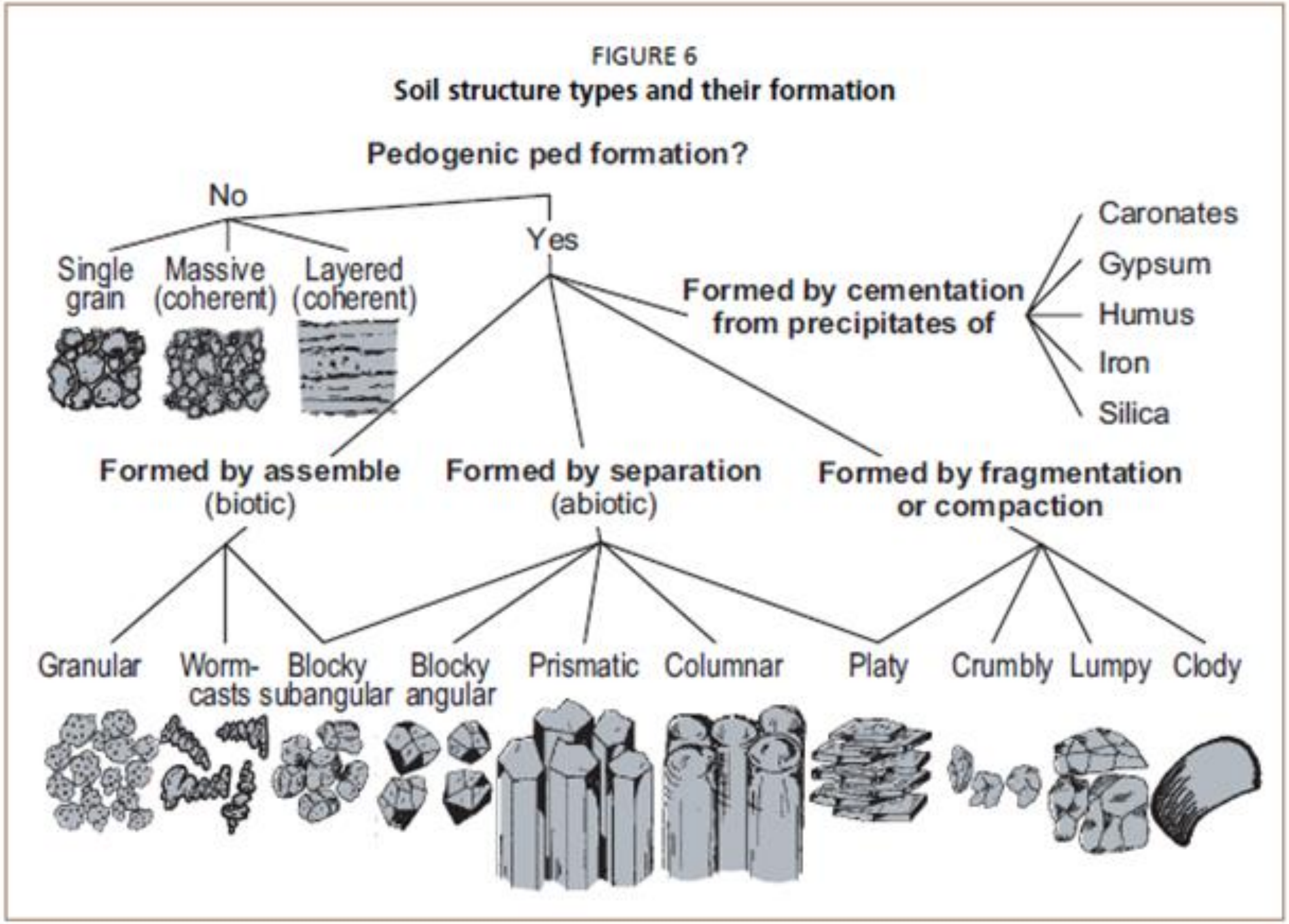
This is why the structure often varies with the depth of the soil, as shown in the diagram below:



The hierarchical organization of soil structure (source: https://wps.prenhall.com/wps/media/objects/5309/5437119/Figures/chapter04.htm)

We observe a finer aggregation, and a structure called "lumpy" or "crumbly" in the surface horizons, where the return or addition of organic matter and biological activity are important.

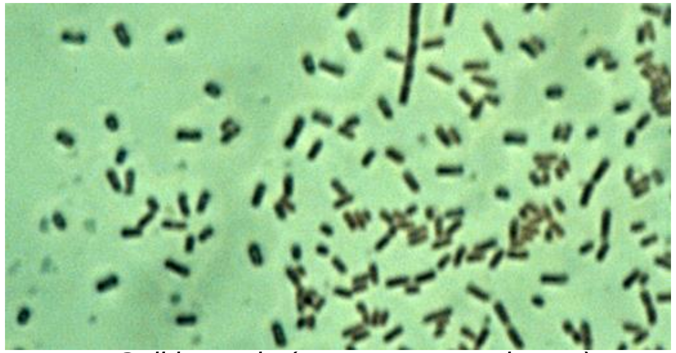
On the scale of a few years, the texture of a soil does not change. The structure of a soil, on the other hand, varies widely according to several parameters: biological activity, climate, root development, cultural practices, bioturbation, fragmentation and / or compaction of the soil, etc. The following diagram illustrates the different structures encountered in soils under the effect of some of these factors, illustrated on the same next slide:



(source: Guidelines for soil description, FAO http://www.fao.org/soils-portal/soil-survey/soil-classification/world-reference-base/en/)

Appendix III – Soil organisms

Bacteria



Soil bacteria (source: nrcs.usda.gov)

Bacteria are one-celled organisms, with diameter of one to a few micro-meters and varying length. A teaspoon of soil contains as much as 100 million to 1 billion bacteria. Bacteria feed preferentially on organic material with high nitrogen content. Bacteria can be categorized in four functional types: Decomposing, symbiotic, pathogenic, and lithotrophs.

- The decomposing bacteria play an important role in nutrient cycling as they need a certain amount of N to be able to consume C from decomposing material. If the C:N ratio of the organic material is too small, the excess N from the organic material is mineralized and made available to plants. On the contrary, if there is a deficit in N in the organic material, nitrogen from the soil solution will be immobilized by the bacteria to be able to consume the C.
- The symbiotic bacteria: These bacteria form mutualistic relationships with the plant. This category includes the nitrogen-fixing bacteria often found in partnership with Fabaceae. Other symbiotic relationships are formed with endophytes (bacteria living inside the root of plants).
- The pathogenic bacteria: Some pathogenic bacteria can harm plants. This category includes all bacterial diseases (blights, wildfires, galls, etc.). A plant with lower immunity (due to all kinds of stresses) and lacking symbiotic microbes are more subject to plant diseases.
- The lithotrophs: these bacteria don't use carbon but other compounds as their main primary source of energy. They play a role in nutrient cycling.

Some bacterial functions:

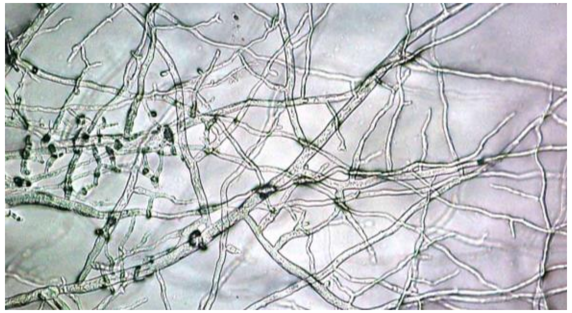
- Nitrogen-fixing bacteria: This category encompasses free-living bacteria as well as symbiotic bacteria (that were mentioned as an example above). The first type includes among others Azotobacteria and some Cyanobacteria. The second type forms symbiotic relationships with plants. The rhizobia, especially, form symbiotic relationships with plants from the Fabaceae family. The bacterium colonizes the root and forms visible nodules that will capture nitrogen from the air and provide it to the plant. In this second type, some other bacteria like Frankia and some Azospirillum species are also found, forming relationships with other plant families. (Encyclopedia Britannica, 2020)
- Nitrifying bacteria: convert ammonium (NH_4^+) to nitrite (NO_2^-) and then to nitrate (NO_3^-). Those bacteria are aerobic.
- Denitrifying bacteria: convert nitrate (NO_3^-) to gaseous forms of nitrogen: dinitrogen (N_2) and nitrous oxide (N_2O). Those bacteria are anaerobic..

Fungi

Fungi are a full-blown Kingdom among the living organisms. Some frequently encountered soil fungi are the Deuteromycota, the Ascomycota and the Basidiomycota. The Basidiomycota family in particular produces fruiting bodies well-known as mushrooms. Fungi in the ground grow in filaments called hyphae. Fungal hyphae have a diameter ranging from 3 to 10 micrometers, which is smaller than root hairs, enabling fungi to reach nutrients located in narrow spaces. In contrast with bacteria, most fungi grow more efficiently on low nitrogen substrates and dominate soils which are less disturbed. (Paul, 2014)

Fungi have powerful enzymes to access nutrients bound in organic matter and on mineral particles, but also possess mechanical pressure abilities. For example, fungi have been boring tunnels through rocks (Frazer, 2015). The oldest and biggest living organism currently on earth is an Armillaria ostoyae (Basidiomycota) in the Oregon Blue Mountains (Mc Rae, 2018). Fungi play also a role in soil structuration though their hyphal network that binds micro-aggregates together to form macro-aggregates.

- **Saprophytic fungi:** Saprophytic fungi are decomposers: they feed on dead organic material. Their secondary metabolites are very stable and complex organic structures with a high carbon content. Therefore, fungi do not only store carbon in their body but also in humus (very stable decomposed organic matter). (Ingham, 2000)



Fungal hyphae (source: forestfloornarrative.com)

- **Pathogenic fungi:** The Oomycota, which are responsible for a number of fungal diseases, have been recently excluded from the fungal Kingdom, but are generally still englobed with fungi in practice.
- **Mycorrhizal fungi:** Mycorrhizal fungi colonize plant roots, meaning they enter the plant tissue through infection sites. They form symbiotic relationships with the plant, which gets more nutrients, show a higher plant growth rate and a better disease resistance. Endomycorrhizal plants can fetch nutrients up to 8 cm from their plants roots, ectomycorrhizal plants can fetch nutriments up to 20 cm from the plant roots, while non-mycorrhizal plants can only get nutriments from a few millimeters around the roots (Suchitra et al. 2020). This stresses the importance of understanding soil fungi, in order to substantially enhance plant growth and crop protection. There are two main types of mycorrhizal fungi, illustrated in the figure thereunder:

- Ecto-mycorrhizal fungi

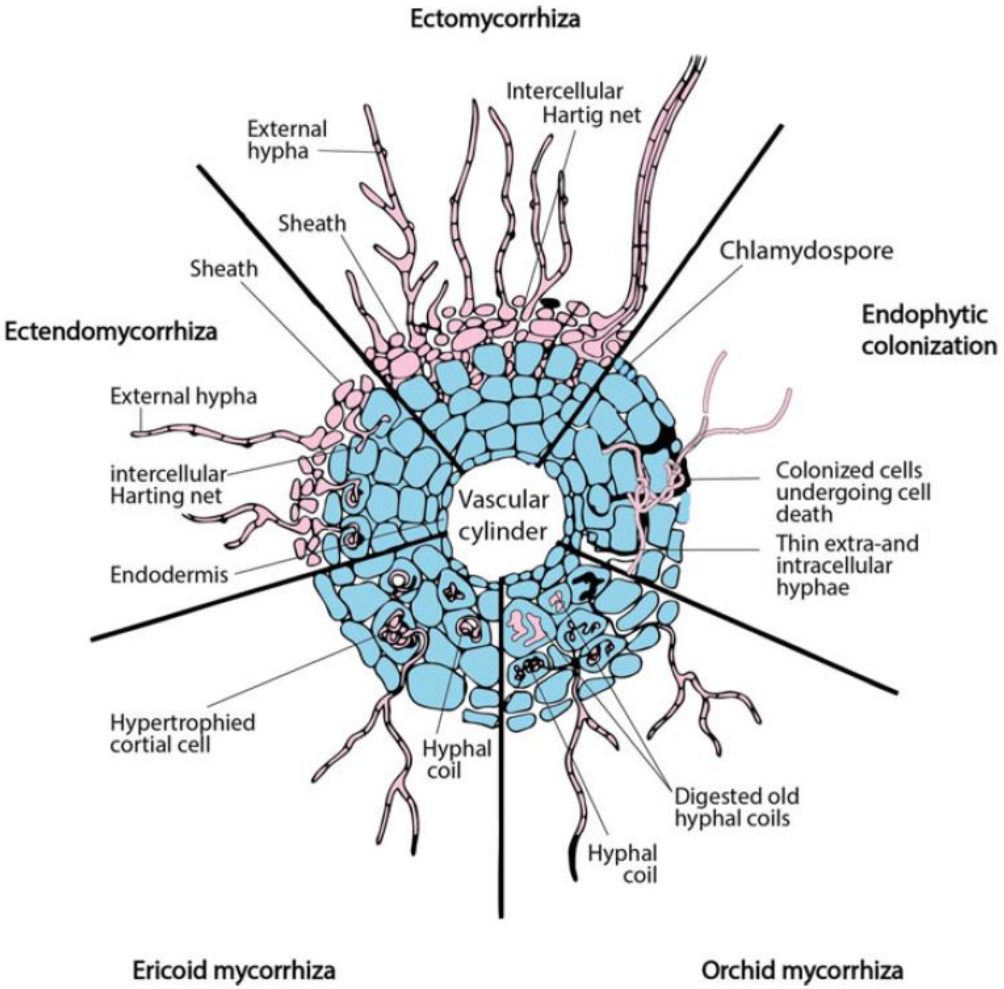
Ecto-mycorrhizal fungi are commonly found in symbiosis with woody plants (pines, trees, vines, etc.). They grow between the epidermal cells but mostly don't enter the root cells themselves. Ecto-mycorrhizae cover and surround the roots, forming a network called the "Hartig net". They suppress root hair growth and replace their function by forming hyphae. They acquire water and nutrients for the plant in exchange for carbohydrates.

- Endo-mycorrhizal fungi
    - ARBUSCULAR MYCORRHIZAL FUNGI (AMF)

This is the most common type of endomycorrhizae. Arbuscular mycorrhizal fungi, on the contrary, penetrate the root cells and form tree-like structures called arbuscles, which are the exchange sites for carbohydrates, nutrients and water. AMF are rather found in symbiosis with herbaceous plants and annual plants.

- OTHER TYPES OF MYCORRHIZAE

Orchids, for example, are unable to perform photosynthesis and use therefore a specific type of relationship with their respective endo-mycorrhizae, forming coils inside the root cells. (Dhanker et al. 2020). Ericoid plants also have a specific relationship, where the mycorrhizal fungus enters the cortical cells.



Root profile with different kinds of mycorrhizal associations (Dhanker et al. 2020)

Protozoa & nematodes

Soil protozoa (source: https://www.fao.org/)

Soil nematodes (source: https://www.nrcs.usda.gov/)

Protozoa

Protozoa are single-celled, with size ranging from 5 to 500µm. Protozoa are the main predators of bacteria, regulating their population, but they also feed on other protozoa, soil organic matter and occasionally fungi, helping regulate the pathogen population as well. They have various shapes and strategies to catch their prey. The most common types of protozoa are Flagellates, Amoebae and Ciliates. Many protozoa have a vacuole containing the excess liquids and nitrogen that they accumulate while eating. This vacuole is regularly released in the soil solution. (Encyclopaedia Britannica, 2019; Ingham, 2000)

- Flagellate: Flagellates have one or two whip-like structures called flagella to move. Flagellates are aerobic organisms.
- Amoebae: Amoebae are relatively large and move using a temporary foot called '"pseudopods". Amoebae are aerobic organisms.
- Ciliates: This is the major group of protozoa. Ciliates have "cilia", which are hair-like structures covering their surfaces. They use their cilia to move around, looking for food. Ciliates are facultative anaerobes, which means that they are more active and efficient in low oxygen conditions than the other protozoa.

Nematodes

Nematodes are small worms with a typical diameter of 50 µm and length of 1 mm. Parasitic nematodes are widely known, but there are also many beneficial nematode species.

- Root-feeding nematodes: Root-feeding nematodes cause damage to crops. Some beneficial fungi create specific ring-shaped traps for these root-feeding nematodes, and then digest their outer membrane to feed on their content.
- Fungal feeding nematodes: these nematodes feed on fungi. They have specific mouth mandibles to attack fungal hyphae.
- Bacterial feeding nematodes: these nematodes feed on bacteria. They have specific mouth mandibles to catch bacteria.
- Predatory nematodes: these nematodes feed on protozoans as well as other nematodes.

Earthworms

Earthworms are well-known organisms in the soil. Their lengths go from a few centimeters to almost two meters. They are found in temperate soils and in tropical soils. They consume dead organic material or sometimes-mineral material and are crucial to nutrient recycling. Earthworm casts improve soil structure.

- Epigeic earthworms: Those earthworms remain on the surface on the ground and decompose dead organic matter. These are the earthworms found for example in compost piles.
- Endogeic earthworms: These earthworms rarely come to the surface of the earth, creating horizontal channels in the sub-soil.
- Anecic earthworms: This type of earthworms bore vertical channels through soil and perform "bioturbation" by bringing organic matter to deeper layers of soil. They permeate the soil, improving water infiltration

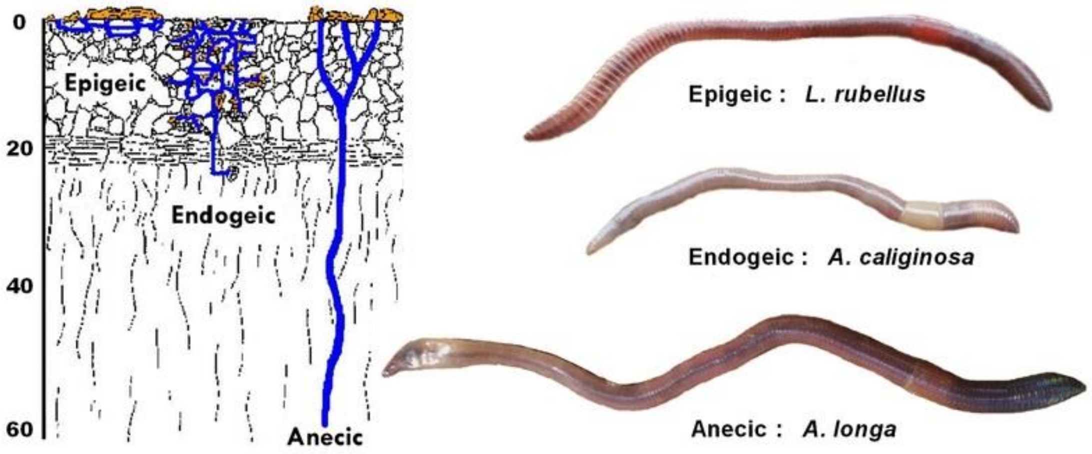


Diagram courtesy of the Science Learning Hub. Figure adapted from Fraser and Boag, photos of earthworms copyright Ross Gray.

Lexicon

- Mineral/organic form: Nutrients are said to be “mineralized” when they are converted to a plant-available form, and to be in “organic form” when they are unable to plants but stored in organic material or organisms.

Appendix IV - Bibliography

- Varma, A., & Tripathi, S. (2020). Plant Microbe Symbiosis. R. Prasad (Ed.). Springer International Publishing.
- Schulze, E. D., Beck, E., Buchmann, N., Clemens, S., Müller-Hohenstein, K., & Scherer-Lorenzen, M. (2019). Plant ecology.
- Gobat, J. M., Aragno, M., & Matthey, W. (2004). The living soil: fundamentals of soil science and soil biology. Science Publishers.
- Darwish, Leila. Earth Repair: A Grassroots Guide to Healing Toxic and Damaged Landscapes, 7th Edition. New Society Publishers. 2013
- Stamets, Paul. Mycelium Running: How Mushrooms Can Help Save the World. Ten Speed Press. 2005
- Cotter, Tradd. Organic Mushroom Farming and Mycoremediation: Simple to Advanced and Experimental Techniques for Indoor and Outdoor Cultivation. Chelsea Green Publishing. 2014.
- LEWIS, W, & LOWENFELS, J. (2010) Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web.

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Student Coursebook: Volume 5 – Science and Natural Laws

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Vol. 5 – Science and natural laws.

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Objectives

- The chapter aim is providing an overview about how Permaculture Design can be considered a scientific method. The purpose is therefore to define linear and non-linear systems, define complexity and its management and to elaborate on ways of creating sustainable communities.
- To do this, the first section describes what the scientific world intends as scientific method, while the following section's purpose is to explain what is Complexity Theory and non-linear systems models, carrying simplest non-linear example, hoping that they can help teachers and students to understand better what means to solve non-linear equations and take confidence with the mathematical phase space and the reading of natural and ecological systemic dynamics.
- We considered that both teachers and student in the undergraduate university have a background preparation in the scientific approach, for this we preferred to avoid a complete and exhaustive treaty of the theory, how much more we wanted to focus their attention to a few concepts and aspects that are functional to better understand the matter.
- With this intent we explore a practical example that is very important for ecologist, biologists, agronomists and permaculturists: the prey-predator model of Volterra-Lotka.

Scientific Method

- Permaculture Design's structure shows a clear scientific ground, and we know that it involves and connects all disciplines: natural science, history, math, design, engineering, physics, geology, biology, soil science, ecology and also psychology and other social sciences (see chapter 4.1.2 of the teachers' book a more in-depth analysis).
- This means that Permaculture is a science indeed, but we also know that it is a science related to the biological systems, that are systems with a very large number of elements, that escape from the deterministic representation of reality, and become unpredictable and so unexpected in their evolution.
- So to date science is dualistic: on the one hand there is a deterministic mechanics, in which is known the initial conditions and the physical laws that describes the phenomenon, one can predicts and exactly expects a certain evolution; on the other hand there is the natural systems dynamics, with their intrinsic complexity, due to the large number of variables, degree of freedom and non-linearity in their description laws, that brings to be strongly dependent on the initial conditions, so that will produce a complex and chaotic evolution: a little variation in the initial conditions can create a huge change in time for the whole system (the so called Butterfly Effect).
- This brings necessarily to a change in our point of view, a change of paradigm.

Complexity Theory

Complexity theory is an interdisciplinary theory that grew out of systems theory in the 1960s. It draws from research in the natural sciences that examines uncertainty and non-linearity.

Complexity theory emphasizes interactions and the accompanying feedback loops that constantly change systems. The term is generally used to characterize something with many parts, where those parts interact with each other in multiple ways, culminating in a higher order of emergence greater than the sum of its parts. The study of these complex linkages at various scales is the main goal of complex systems theory.

In fact, one of the peculiar properties of the whole living world is the tendency to form multilevel structures of systems within other systems: each of these structures forms a totality with respect to its parts and is at the same time part of a larger whole.

This dual role of living systems, as parts and totals, requires the interaction of two opposing tendencies: an integrative tendency and a self-organizing tendency to preserve individual autonomy.

This interaction leads to the existence of different levels of complexity with different laws that operate at each level: at each level of complexity, the phenomena observed exhibit properties that do not exist at a lower level. These properties are called "emerging properties" and the concept behind these behaviours is that of "complex organized entity ".

This systemic approach, applied to ecology, the study of the relationships between organisms and their habitat, permitted to introduce the important concept of “ecosystem”, that characterizes the communities of plant and animals interacting in their natural contests, and the concept of “network”, the functional relationships between the different organisms, their parts and their communities.

These concepts together bring to the non-hierarchical vision of the world and his phenomena, but a sort of holistic vision in which the three kinds of living systems, organisms, parts of organisms and communities of organisms, as an integrated whole, interact one with the others creating a sort of web of exchange of matter and energy flows. Because different levels exist, we can imagine a sort of web of webs, like a fractal picture, in which we can see the intersections, that are called knots, and every knot represents an organism, that will appear as a web, if we enlarge the vision.

The systemic approach means to shift perceptions from objects and material structures to processes and organizational patterns that represent the very essence of the living, as a paradigm shift that brings the perspective from the parts to the whole.

While in the mechanistic view the world is a set of objects that interact with each other, with relationships of a secondary order, in systemic thought it is precisely these relationships that are important, while objects are secondary.

It should also be clarified that the emphasis on relationships, qualities and processes does not mean that objects, quantities and structures no longer matter. Simply when talking about a change of perspective it does not mean that systemic thinking completely eliminates one in favour of the other, but rather that there is a complementary interaction between the two visions, exactly as has happened in the history of physics so many times.

Complexity Theory

The shift of perspective, the change of paradigm, does not happen in a simple way, because in science things must be measured, weighed and repeatable. But the connections between the elements can never be so in the deterministic sense, and if they cannot be measured, they can instead be mapped. The transition between measurement and mapping is crucial, because we will discover that certain configurations occur repeatedly, creating what we call patterns.

Studying patterns is a qualitative approach, no longer quantitative and systemic thinking has certainly accelerated the transition from quantity to quality, developing all that area of study, which is the theory of complexity.

As it was introduced, the theory of complexity is a new mathematics, a mathematics of visual models, that is, which allows, in a virtual space (phase space) to see the entire dynamics of the system, state by state, dynamics that manifests more the preservation of the form, of the general characteristics of the whole rather than the specific ones of a single organism (attractors, strange attractors).

To summarize all these concepts we can say that the mechanist paradigm is based on the Cartesian idea of the certainty and accuracy of scientific knowledge, in the systemic paradigm instead, it is recognized that all scientific concepts and theories are limited and approximate.

This limitation must not be discouraging for the scientific community, just as quantum mechanics has not been with the introduction of the Heisenberg uncertainty principle, on the contrary, the fact that it is possible to formulate approximate but absolutely effective models and theories to describe an infinite network of related phenomena and that, thanks to super computers, the approximation can be improved over time must encourage research in this direction even more.

In light of what has been said, it is clear that living systems are actually self-organized networks, the elements of which are all interconnected and interdependent. Their networks are so complex that only powerful computers have allowed scientists and mathematicians to develop new concepts and techniques to deal with their boundless complexity, giving rise to the commonly known complexity theory, more technically defined as nonlinear dynamics or systems theory nonlinear or simply theory of dynamic systems. Chaos theory and fractal geometry are important branches of this new mathematics.

As we have already guessed it is a mathematics of relationships and patterns: when solving a non-linear equation with these techniques the result is not a formula but a visual figure, a shape drawn by the computer and both the attractors of the physics of the chaos that fractals of fractal geometry are excellent examples of such patterns. For this reason, the theory of complexity follows the paradigm shift characteristic of systemic thought.

The existence of a patterns that describes the whole behaviour of the systems means that while it is true that the dynamics of the system is unpredictable, it is true also that still exists an order in the apparent disorder and that they are also constrained by order-generating rules.

Complexity Theory

Complexity has two faces in science:

- There is the complete disorganized complexity such as in a gas in a container, with the gas molecules as the parts. Some would suggest that a system of disorganized complexity may be compared with the (relative) simplicity of planetary orbits – the latter can be predicted by applying Newton's laws of motion. Of course, most real-world systems, including planetary orbits, eventually become theoretically unpredictable even using Newtonian dynamics; as discovered by modern chaos theory.
- And organized complexity, resides in nothing else than the non-random, or correlated, interaction between the parts. These correlated relationships create a differentiated structure that can, as a system, interact with other systems. The coordinated system manifests properties not carried or dictated by individual parts. The organized aspect of this form of complexity vis-a-vis to other systems than the subject system can be said to "emerge," without any "guiding hand".

Complexity

- The number of parts does not have to be very large for a particular system to have emergent properties. A system of organized complexity may be understood in its properties (behaviour among the properties) through modelling and simulation, particularly modelling and simulation with computers. An example of organized complexity is a city neighbourhood as a living mechanism, with the neighbourhood people among the system's parts.
- In several scientific fields, "complexity" takes a precise meaning, the most interesting fields are:
- In information processing, complexity is a measure of the total number of properties transmitted by an object and detected by an observer. Such a collection of properties is often referred to as a state.
- In physical systems, complexity is a measure of the probability of the state vector of the system. This should not be confused with entropy; it is a distinct mathematical measure, one in which two distinct states are never conflated and considered equal, as is done for the notion of entropy in statistical mechanics.
- In dynamical systems, statistical complexity measures the size of the minimum program able to statistically reproduce the patterns (configurations) contained in the data set (sequence). While the algorithmic complexity implies a deterministic description of an object (it measures the information content of an individual sequence), the statistical complexity, like forecasting complexity, implies a statistical description, and refers to an ensemble of sequences generated by a certain source. Formally, the statistical complexity reconstructs a minimal model comprising the collection of all histories sharing a similar probabilistic future and measures the entropy of the probability distribution of the states within this model. It is a computable and observer-independent measure based only on the internal dynamics of the system, and has been used in studies of emergence and self-organization
- In Network theory complexity is the product of richness in the connections between components of a system and defined by a very unequal distribution of certain measures (some elements being highly connected and some very few, see complex network).

The Non-linearity problem

- In mathematics and science, a **nonlinear system** is a system in which the change of the output is not proportional to the change of the input. Nonlinear problems are of interest to engineers, biologists, physicists, mathematicians, ecologists and many other scientists because most systems are inherently nonlinear in nature: nature is inexorably nonlinear. Nonlinear dynamical systems, describing changes in variables over time, may appear chaotic, unpredictable, or counterintuitive, contrasting with much simpler linear systems.
- Typically, the behaviour of a nonlinear system is described in mathematics by a **nonlinear system of equations**, which is a set of simultaneous equations in which the unknowns (or the unknown functions in the case of differential equations) appear as variables of a polynomial of degree higher than one or in the argument of a function which is not a polynomial of degree one. In other words, in a nonlinear system of equations, the equation(s) to be solved cannot be written as a linear combination of the unknown variables or functions that appear in them. Systems can be defined as nonlinear, regardless of whether known linear functions appear in the equations. In particular, a differential equation is *linear* if it is linear in terms of the unknown function and its derivatives, even if nonlinear in terms of the other variables appearing in it. Examples of nonlinearity are the presence in the equations of variables describing friction or dependent to the velocity.
- As nonlinear dynamical equations are difficult to solve, nonlinear systems are commonly approximated by linear equations (linearization). This works well up to some accuracy and some range for the input values, but some interesting phenomena such as chaos, and singularities are hidden by linearization. It follows that some aspects of the dynamic behaviour of a nonlinear system can appear to be counterintuitive, unpredictable or even chaotic. Although such chaotic behaviour may resemble random behaviour, it is in fact not random. For example, some aspects of the weather are seen to be chaotic, where simple changes in one part of the system produce complex effects throughout: butterfly effect. This nonlinearity is one of the reasons why accurate long-term forecasts are impossible with current technology.

A simple example to better understand the new mathematics behind nonlinearity is the Volterra-Lotka model to describe the prey-predator problem

The prey-predator dynamic is very interesting. It is typical of any ecosystem in which there are mainly 2 different animal species.

In this context we take prey (rabbits) and predators (foxes) for simplicity, but they could also be aphids and ladybugs.

The goal we set ourselves is to model this situation, so that we can predict the growth regimes that characterize both species.

Obviously, this dynamic can be influenced by many factors, but for our purposes, namely understanding the paradigm shift, we will simplify it considerably, so that we can trace it back to the use of the famous Volterra-Lotka model. In fact, it is able to describe this context with an interesting degree of precision.

First of all, we are analyzing a Dynamic System, that is a system in which the conformation that the 'objects' assume in play varies over time, in fact the percentage of rabbits (and similarly of foxes) compared to the total 'population' varies as a function of time.

To characterize the changes that occur in a dynamic system, a differential equation is usually used (in the simplest case), but as soon as the context becomes a little more complicated, we inevitably switch to using systems of differential equations, often nonlinear.

In our example, the system is described by a system of 2 first order nonlinear differential equations, slightly simplified by the fact that our x and y variables describe animal populations, that is, something concrete and countable in positive integers, so we will reason with variables not negative

We then use the variable x to indicate the number of prey, while the variable y to indicate the number of predators.

It is immediately intuitive how, whatever relationship we are going to introduce, the dynamics of the analysed system will contrast the increases of the two populations.

That is, there will be a period in which the preys increase and consequently also the predators as they have more nourishment; then a 'critical' point will follow where the prey will no longer be sufficient to feed the new predators, which will therefore decrease.

Consequently, the prey can reproduce more without risking being decimated and consequently they will increase again, to close the cycle and return to a situation similar to the initial one, the prey will now be sufficient to feed more predators and therefore increase them in number.

A simple example to better understand the new mathematics behind nonlinearity is the Volterra-Lotka model to describe the prey-predator problem

The trend we expect will be of a harmonious type, more or less of this type:

It should be noted that the trend of predators and prey is periodic. As we can guess, at a prey peak a predator's peak occurs which in turn causes a minimum of the preys followed by a decrease of the predators.

Without a model, it is difficult to describe a situation like that fairly accurately. This is precisely the beauty of the models; they are almost like frames able to clarify multiple contexts that are different but similar for some characteristics.

Here, the Volterra-Lotka model is able to clarify the prey-predator problem, highlighting the dynamics that occur between these two antagonistic populations.

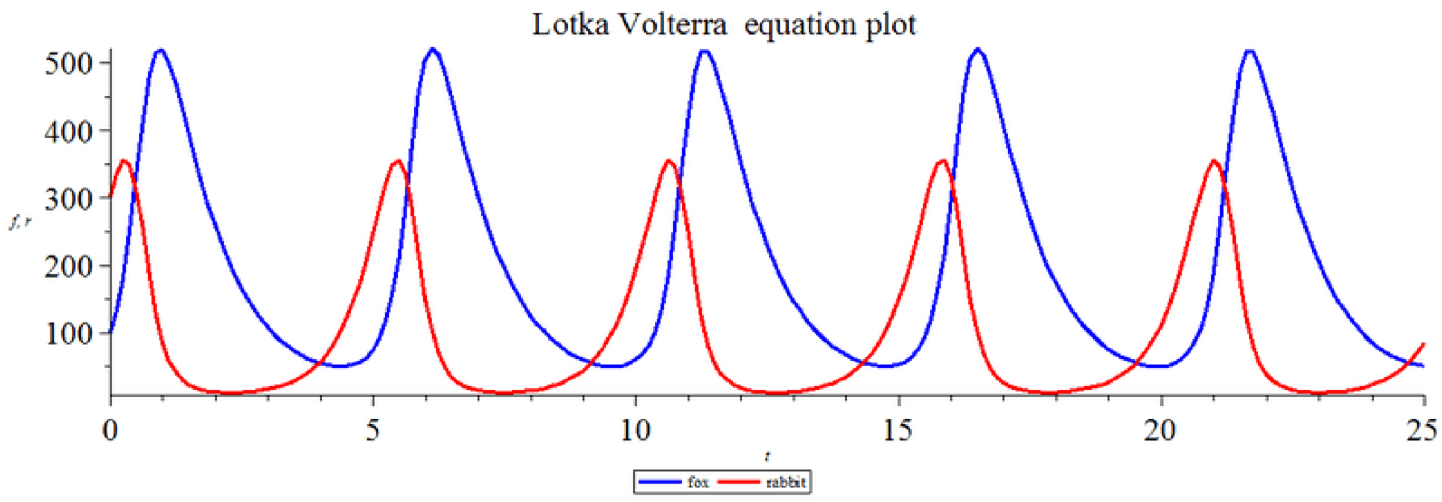
Here is the system that defines this model:

dxdt=A-Byx

dydt=Cx-Dy

Where '*x*' and '*y*' are both positive for this said before, and *A, B, C, D* are constants that vary according to the pair of populations being analysed, they practically serve to 'weigh' the effect that one population has on the other.

To analyse this model in more depth, slightly more advanced concepts are needed such as that of stability, invariant, prime integral and Dini's theorem, but we assume that they are part of the background study.



Volterra-Lotka model to describe the prey-predator

So, try to analyze that system:

Let's assume that predators (*y*) don't exist, so we put *y = 0*. The problem would therefore be simplified considerably.

The system would be reduced to a single equation: it remains only the first of the two

dxdt=Ax

From this, we can deduce how the prey (*x*) would grow exponentially, an absolutely intuitive thing. Symmetrically, predators (*y*), if there were no prey (*x*), would always decrease exponentially. It can then be seen that the growth rate of the prey is reduced in proportion to the number of predators (as we had anticipated in the introduction). In fact, developing the product in the first equation, you notice how a term – *Byx* appears, to show that the more the prey, the slower the growth of *x* will be. A particular conformation of the model

An interesting case is that in which – *Byx* it is larger than *Ax*, in fact in such circumstances we will have a negative increase in the prey, that is, the prey will decrease.

But let's see what happens to predators in the event that their prey decreases, so we can compare the actual findings that we can verify in reality (observing foxes and rabbits in the wild for example) with the results provided by this mathematical model. We recall that a model is useful for representing and analysing reality as long as it provides results compatible with the real context. So let's see how predators (*y*) behave if we follow the model. Evidently here too, we have a decrease in the speed with which the number of predators increases proportionally to the decrease in prey. In other words, more *x* is 'bigger' faster the predators grow, in fact in the second equation a term *Cx* appears.

There is a correct difference in the second equation compared to the first, in fact if you look at it well you will notice how the growth rate of predators decreases proportionally to the number of predators that are present. In fact, a term -*Dy* appears. That means that the more predators there are, the less the increase in *C* prey will be 'useful' to increase the number of predators. In practical terms, if I have one predator and 2 preys, the growth of predators is much faster than if there are already 10 predators that should share the 2 preys, not many for 10 foxes!

With this we have made a fairly general analysis of the problem and of the reasons that lead us to say that the Lotka-Volterra model is effective in analysing this problem.

Before concluding, however, I want to add two important analyses:

1. The existence of a balance

2. The cyclicity of the model

Volterra-Lotka model to describe the prey-predator

1. Existence of a balance

What is meant by balance? Here we would have to say, but in practical terms we mean equilibrium in the plane, given a dynamic system defined on it, an ordered pair (*a,* b) such that, the system evaluated in *x* = *a* and *y* = *b*, leads to have as result the vector (*0,0*).

In more formal and general terms, given an autonomous system

dxdt=f(xt)

the vector x0 is an equilibrium point if

fx0= 0

While in more concrete terms, we say (*a, b*) equilibrium point, if in it the *x* and *y* do not vary, we will in fact have dxdt= dydt = *0*.

So, the point that satisfies these conditions in this V-L model exists and has coordinates (*D / C*, *A / B*). In fact, if we try to replace, it is exactly dxdt= dydt = *0*.

There is another point of equilibrium, perhaps less interesting as it is a very extreme case, and it is the point (0,0). In fact, even in this case we will have dxdt= dydt = *0*.

The latter corresponds to the extinction of both species: if the two populations have *0* individuals, then they will continue to have *0* individuals in each subsequent instant.

The first balance, on the other hand, corresponds to the situation in which predators meet and eat, in each unit of time, a number of preys exactly equal to the number of preys that are born, and this number of prey corresponds precisely to the critical food threshold that makes it remain stationary the population of predators.

The population of preys and predators will therefore not vary in either of the two previous cases!

We can go further by analysing the stability in time of these points, which is quite interesting above all for complex ecosystems with a lot of biodiversity. For the moment we just need to know that extinction is a very difficult condition, unless you start in this condition: it can only happen if the preys are completely extinct in an artificial way, causing the death of predators due to lack of food. If, on the other hand, predators are extinct, the population of prey grows without limit in this simple model.

Volterra-Lotka model to describe the prey-predator problem

On the cyclicity of the Volterra- Lotka model

It can be deduced that in a generic situation with two initial populations *x* and *y* the system has an oscillating behaviour, that periodically returns to its initial state, with very large oscillations as well (see the equation plot above).

This means that the system is simply destined to return to its original condition after more or less prolonged times.

Here we are above all interested in pointing out how this model is a simplification of the respective real situation.

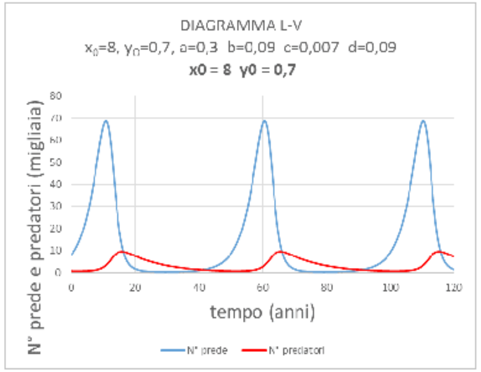
In fact, what is considered in this model is a situation in which, ideally, there are only these two populations, no external factor influencing the progress of their respective growths. How they were isolated from the outside world. In a case like this we can notice the periodicity of the system, because in reality this is not always the same. For example, suppose we are in a non-ideal context (with third factors in play), with an initial situation with 10 rabbits and 5 foxes, and suppose a third component is added to the 'game', 10 poachers go hunting.

For simplicity, let's also assume that these poachers are good enough to kill all the foxes before they can eat a few rabbits.

What will happen now is that we will have $y = 0$, and as seen at the beginning of the discussion, the prey (x) will now grow exponentially!

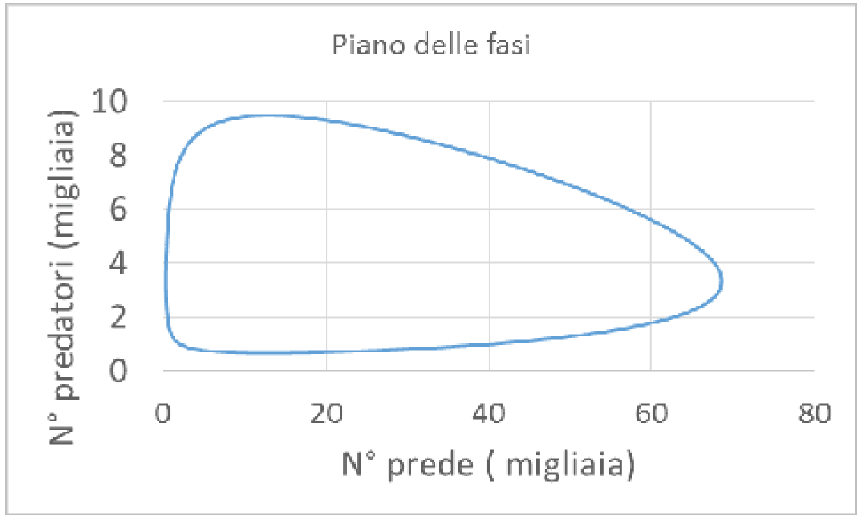
But this could seem strange, because we should periodically return to the initial situation. Clearly we will never go back at the exact same point, because the system is nonlinear, highly dependent from initial conditions and for the butterfly effect, after a time the state of the system is very far from the expected point. Besides it is intuitive that in this simplified model it is impossible that we can go from having *0* foxes to having some, now that the rabbits are growing free and exponentially!

To better understand what said before, about the phase space and the patterns dynamics, we go to see another similar example of system prey – predator and his solution:



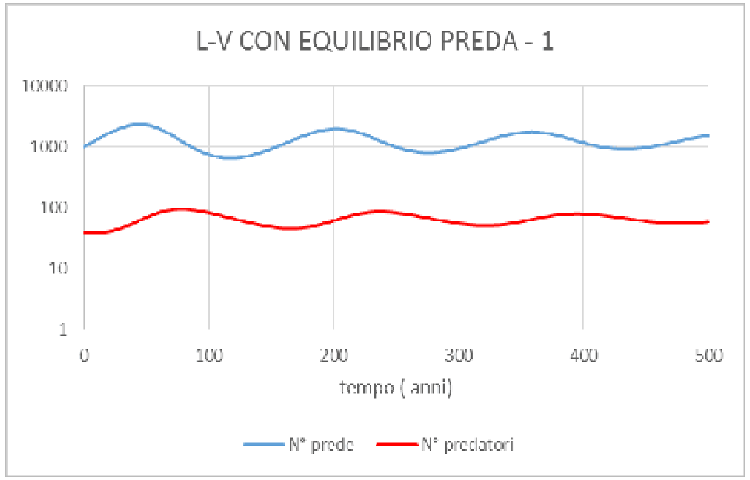
Volterra-Lotka model to describe the prey-predator problem

- It should be noted that the trend of predators and prey is periodic. As you can guess, at a prey peak a predator’s peak occurs which in turn causes a minimum of the preys followed by a decrease of the predators.
- It is also possible to report the dependence of y on x in the diagram, called the Phase Plan Diagram or Phase Portrait: in practice we have eliminated the time variable from the previous diagram and put the number of preys (x) in direct relation with the number of predators (y), according to the phase space rules and conjugated coordinates.
- This diagram, apparently very strange, is understood when compared with the previous diagram. It can be seen that periodic oscillations as a function of the time of the previous diagram are represented here by a closed cycle, which is carried out several times in an anticlockwise direction. Let's start from the bottom left. We assume that in the initial year there is a very limited number of prey and predators, 8000 and 700 respectively. The preys have the opportunity to reproduce and grow rapidly (up to about 70,000). At this point, predators have food in abundance and reproduce up to over 3,000 units. Due to the increase in predators, the preys begin to drop to less than 10,000 units. Now the predators, which had almost reached 10,000 units, due to lack of food, begin to drop rapidly returning to the original 700 units. In this way the cycle closes. The cycle then repeats itself and when time tends to infinity the cycle will be repeated infinite times: this is called the limit cycle.

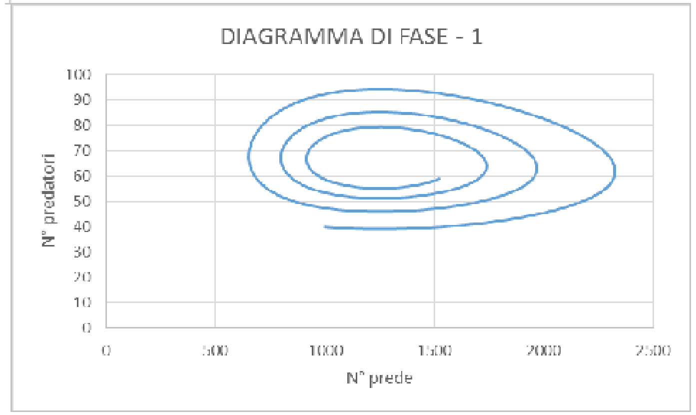


Volterra-Lotka model to describe the prey-predator problem

- The model can be integrated and, according to the values of the constants and the initial conditions, different behaviours can be obtained.
- For example, of this type:

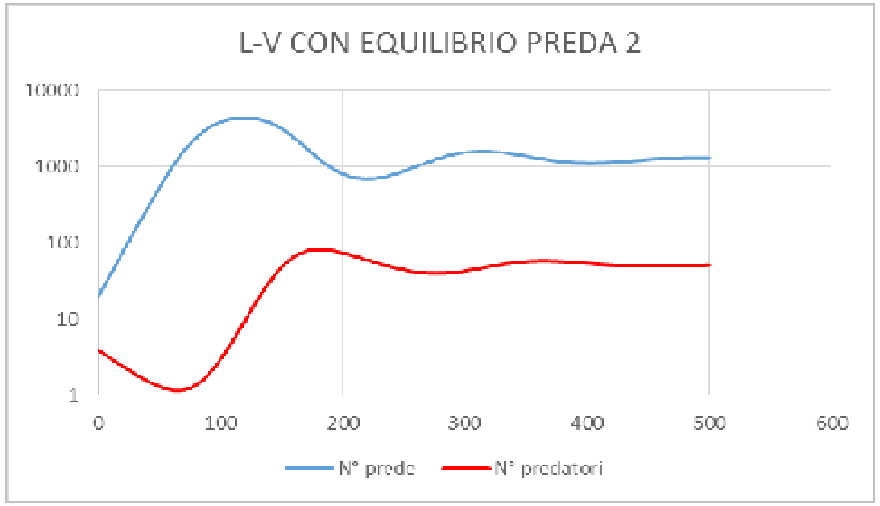


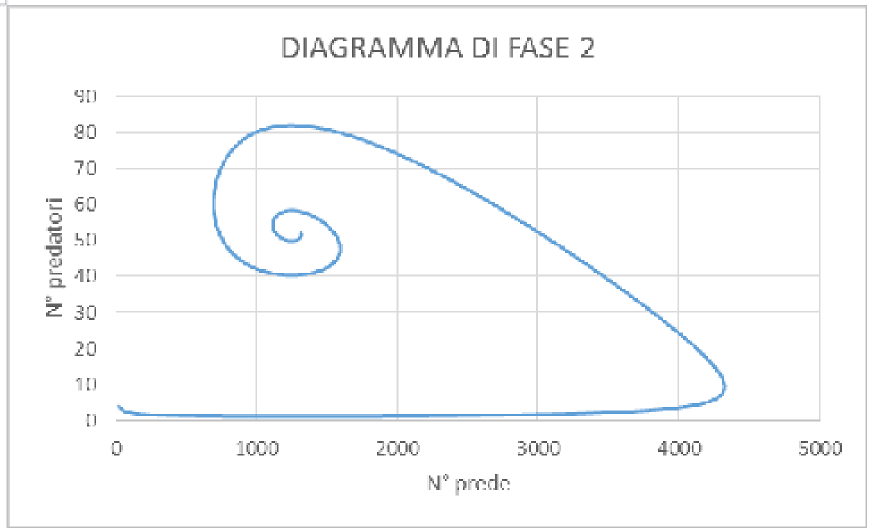
Where one sees that cyclical behaviour is not repetitive. Damped oscillations are obtained, as appears from the second phase diagram, which produce a spiral wound counter clockwise inward.



Volterra-Lotka model to describe the prey-predator problem

In the case that the constant is much lower, the following trend can be obtained instead:





Notice that in both examples 1 and 2 above the spiral wraps itself tending towards the equilibrium point, which is obtained by resetting the derivatives of the function equal to zero, as explained above.

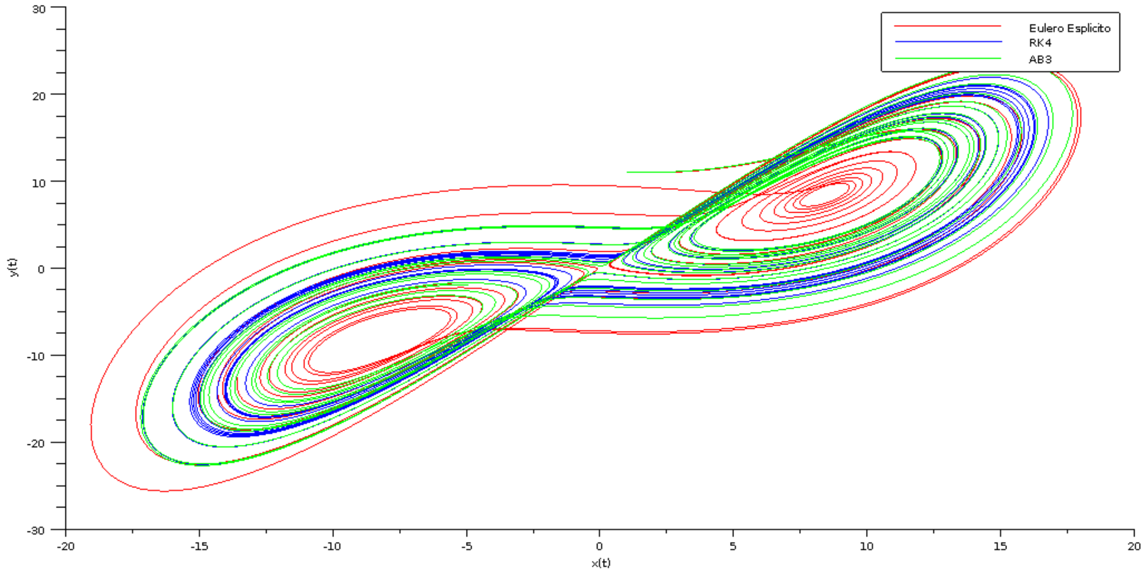
Notice also that every point of the diagram in 1 and 2, represents the “state” of the whole system in each time, state described by the conjugated coordinates.

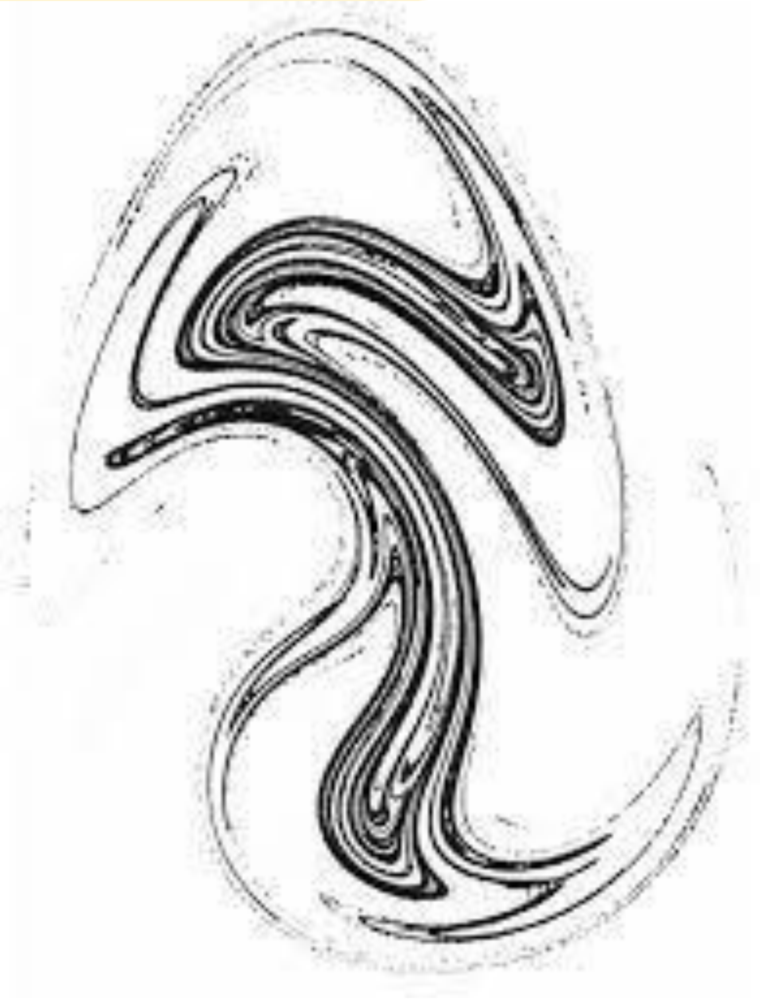
According to what discussed before, these spirals are the attractors of the system that tend to the equilibrium point.

These attractors are nothing but the natural patterns that are fundamental in understanding nature and its phenomena around us.

To better understand the sense of order that emerge from the apparent chaos of nonlinear systems, we want to show some historical strange attractors as we can see in the phase space representation.

Lorenz's Butterfly





Ueda's Strange Attractor

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Volume 6 – Pattern Understanding

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Pattern Understanding

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Pattern Understanding

"The curve described by the earth as it turns is a spiral and the pattern of its moving about the sun… The solar system itself being part of a spiral galaxy also describes a spiral in its movement… Even for the case of circular movement, when one adds in the passage of time, the total path is a spiral… The myriad things are constantly moving in a spiral pattern … and we live within that spiral movement.

(Hiroshi Nakamura , from Spirulina: Food for a Hungry World, University of the Trees Press, P.O. Box 66, Boulder, California 95006, USA.)

The patterns and forms of a tree are found in many natural and evolved structures: an explosion, event, erosion sequence, idea, germination or rupture at an edge or interface of two systems or media (here, earth and atmosphere) may generate the tree form in time and space. Many threads spiral together at the point of deformation or the surface and again disperse. The tree form may be used as a general teaching model for geography, ecology and evolution: It portrays the movement or energy and particles in time and space. Fetus and placenta; vertebrae and bones; vortices; mushrooms and trees; the internal organs of man; the phenomena of volcanic and atom bomb explosions; erosion patterns of wave, rivers and glaciers; communication nets; industrial location nets; migration; genealogy; and perhaps the universe itself are of the general tree form portrayed.

Simple or multiple pathways describe yin yang, swastika, infinity and mandala symbols. A torus of contained forces evolves with the energies of the pattern. Like the doughnut of smoke that encircles the pillar or the atomic explosion. (Bill Mollison, Permaculture One, 1978)

Everything the Power of the World does is done in a circle… The Wind, in its greatest power, whirls… The life of a man is a circle from childhood to childhood and so is everything where power moves. Our teepees were round like the nests of birds and these were always set in a circle. The nation's hoop, a nest or many nests"(Bill Mollison, Permaculture Design Manual , 1988)

Pattern Understanding

What exactly is a pattern?

It is useful to have an ambiguous definition, on purpose, because we actually know it when we see it. Traditionally, we think of patterns as something that just repeats again and again throughout space in an identical way, sort of like a wallpaper pattern. But many patterns that we see in nature aren't quite like that. We sense that there is something regular or at least not random about them, but that doesn't mean that all the elements are identical. I think a very familiar example of that would be the zebra's stripes. Everyone can recognize that as a pattern, but no stripe is like any other stripe.

Anything that isn't purely random has a kind of pattern in it. There must be something in that system that has pulled it away from that pure randomness or at the other extreme, from pure uniformity.

That’s the reason for the link with the Theory of Chaos and Complex Math.

What is Pattern?

- Patterns can be reduced, according to Geoff Lawton, to a General Core Model of Events
- Patterns surround us from the Macro (Stars, the Universe) to the Micro and they are everywhere.
- Patterns are hard to measure, but easy to observe. They are always in front of us but we can’t see the categories unless they have been pointed out to us. However, Elements in the Pattern can be measured (Fibonacci's Series, Golden Ration)
- They look Random but they are not Random. These effects have a cause in Natural Laws. They are, actually, quite precise and measurable, memorable and repeatable.
- Patterns are Form and, even more, an “*Event of Form*” (Lawton) (Examples), because there are factors determining their appearance. There are only a few types of Pattern Form Types, with an infinite number of variations, personality, uniqueness and individuality.
- Patterns are the Way that the Form is created by pressure between two Media or multiple Medias and the Interaction of Energies.This Pressure or Intrusion Creates a Form. (Examples)
- Representations of Nature in its most concise form
- “*Patterning is the way we frame our designs, the template in which we fit the information, entities, and object assembled from observation, map overlays, the analytic divination of connections, and the selection of specific materials and technologies. It is this patterning that permits our elements to flow and function in beneficial relationships*.” (Mollison)

Pattern Understanding

The curl of a chameleon's tail, the spiral of a pinecone's scales and the ripples created by wind moving grains of sand all have the power to catch the eye and intrigue the mind. When Charles Darwin first proposed the theory of evolution by natural selection in 1859, it encouraged science enthusiasts to find reasons for the natural patterns seen in beasts of the land, birds of the air and creatures of the sea. The peacock's plumage, the spots of a shark must all serve some adaptive purpose, they eagerly surmised

Patterns in nature are visible regularities of form found in the natural world. These patterns recurs in different contexts and can sometimes be modelled mathematically. Natural patterns include symmetries, trees, spirals, meanders, waves, foams, tessellations, cracks and stripes

There are three worthwhile activities to attempt about pattern:

- 1. PATTERN UNDERSTANDING: Observation and creation of pattern models, as examples of natural phenomena that demonstrate such models.
- 2. A LINKING DISCIPLINE: geography, geology, music, art, astronomy, particle physics, economics, physiology, and technology are connected by a recognized application of pattern
- 3. PATTERN APPLICATION: design with a conscious application of harmonic pattern in the design itself or in the Information flow and processes. This path leads the designer to the celebration of the comprehension of the meaning of nature and life.

A database of inspirational patterns

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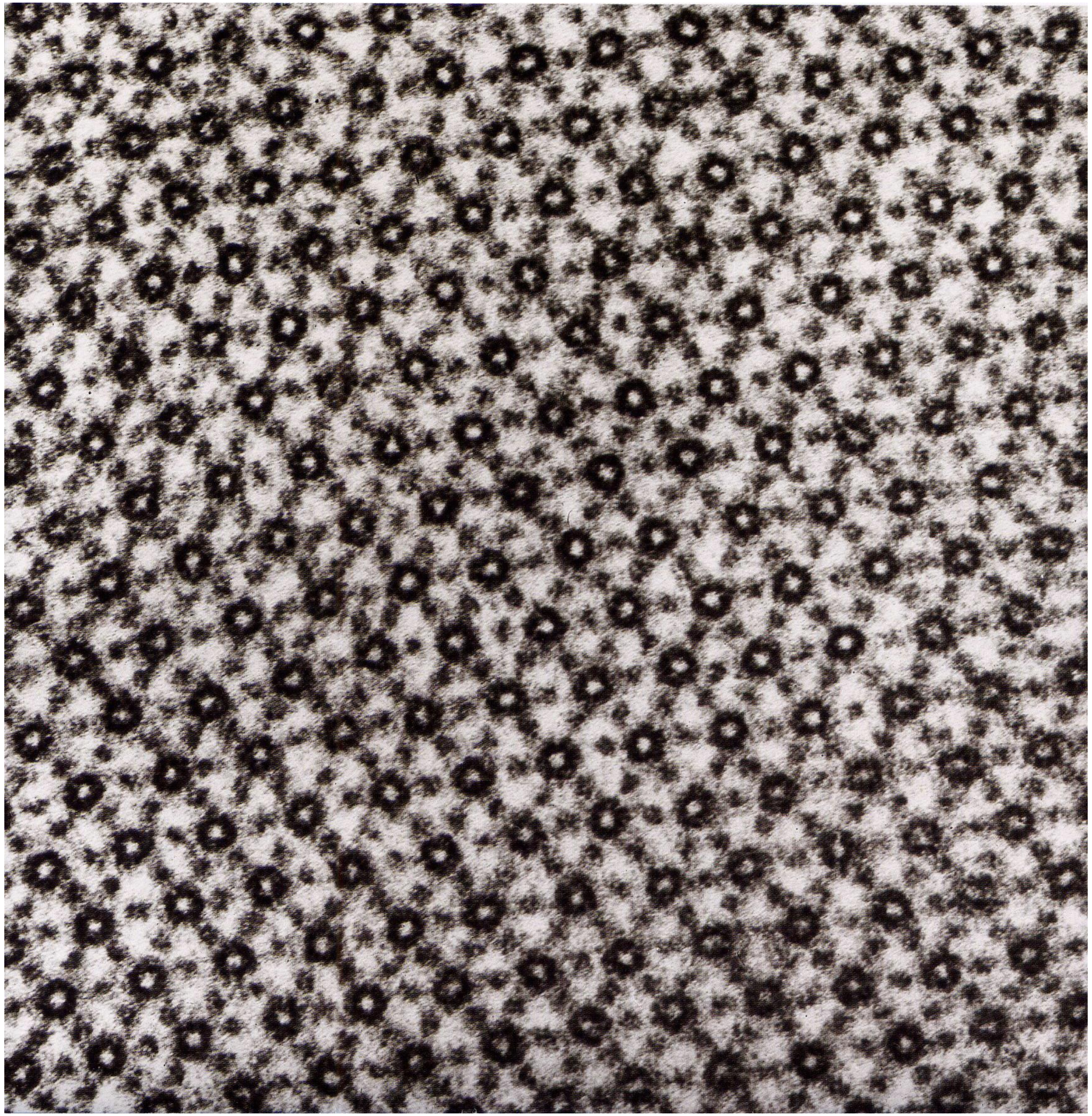

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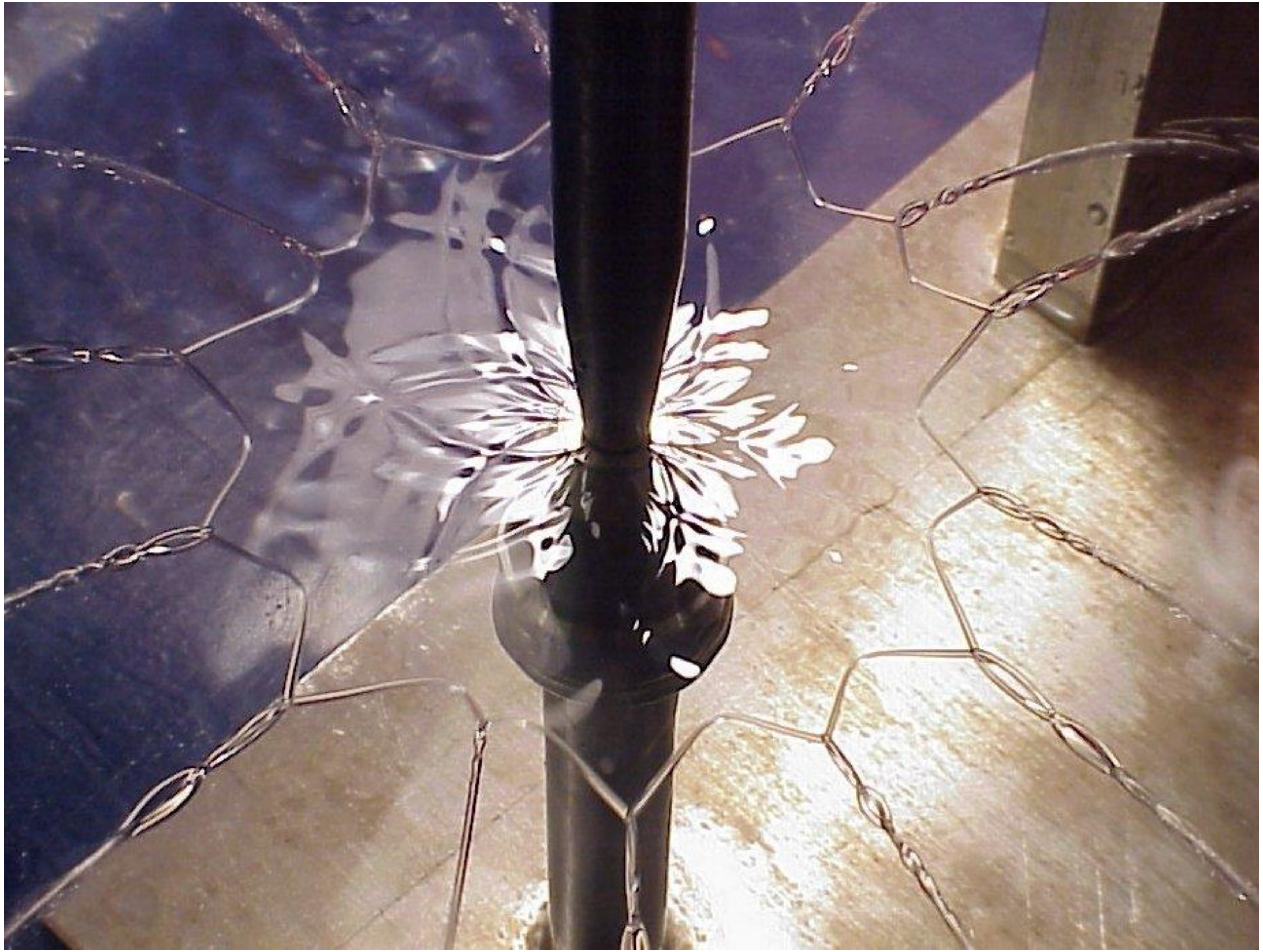
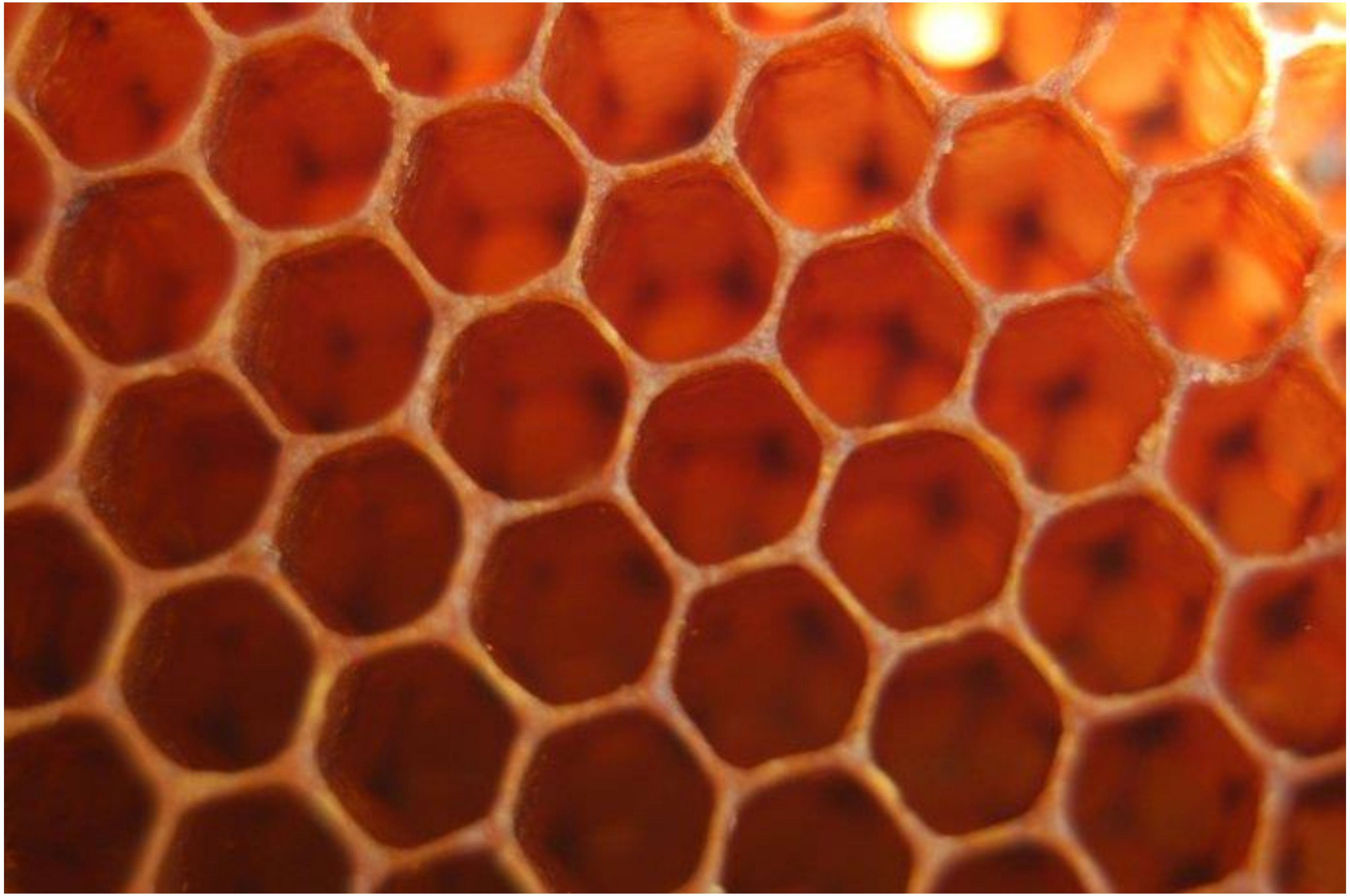
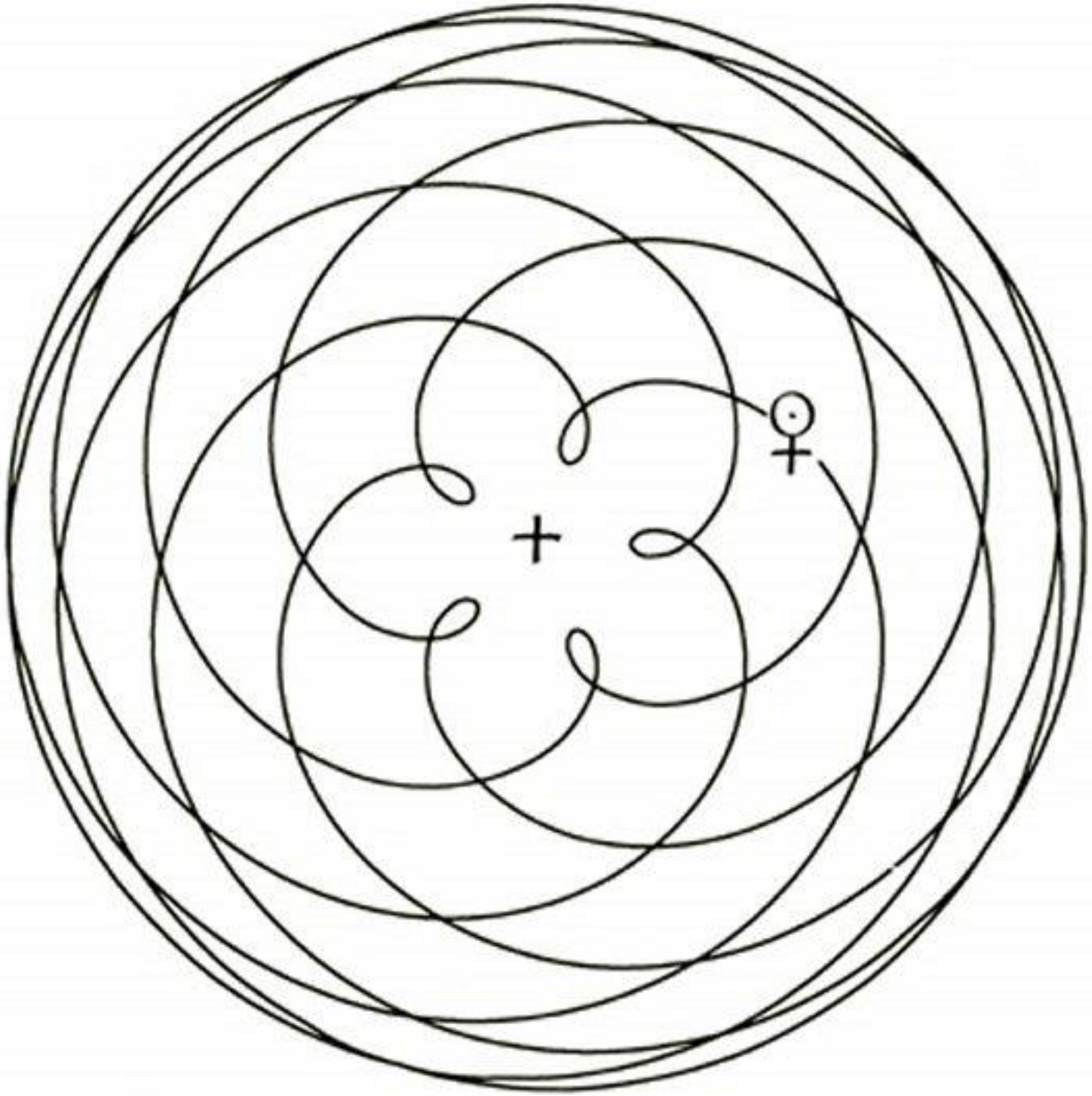
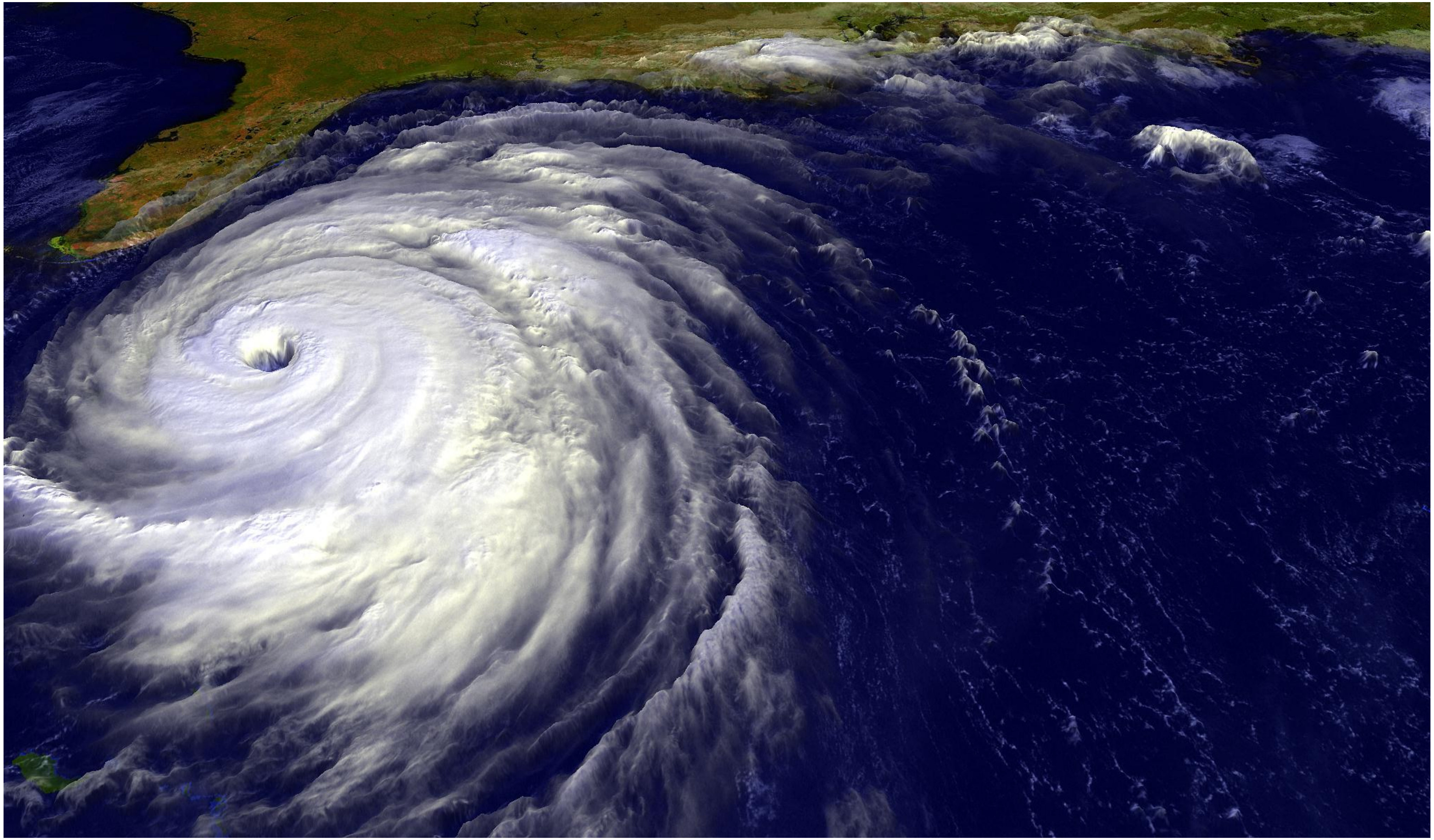


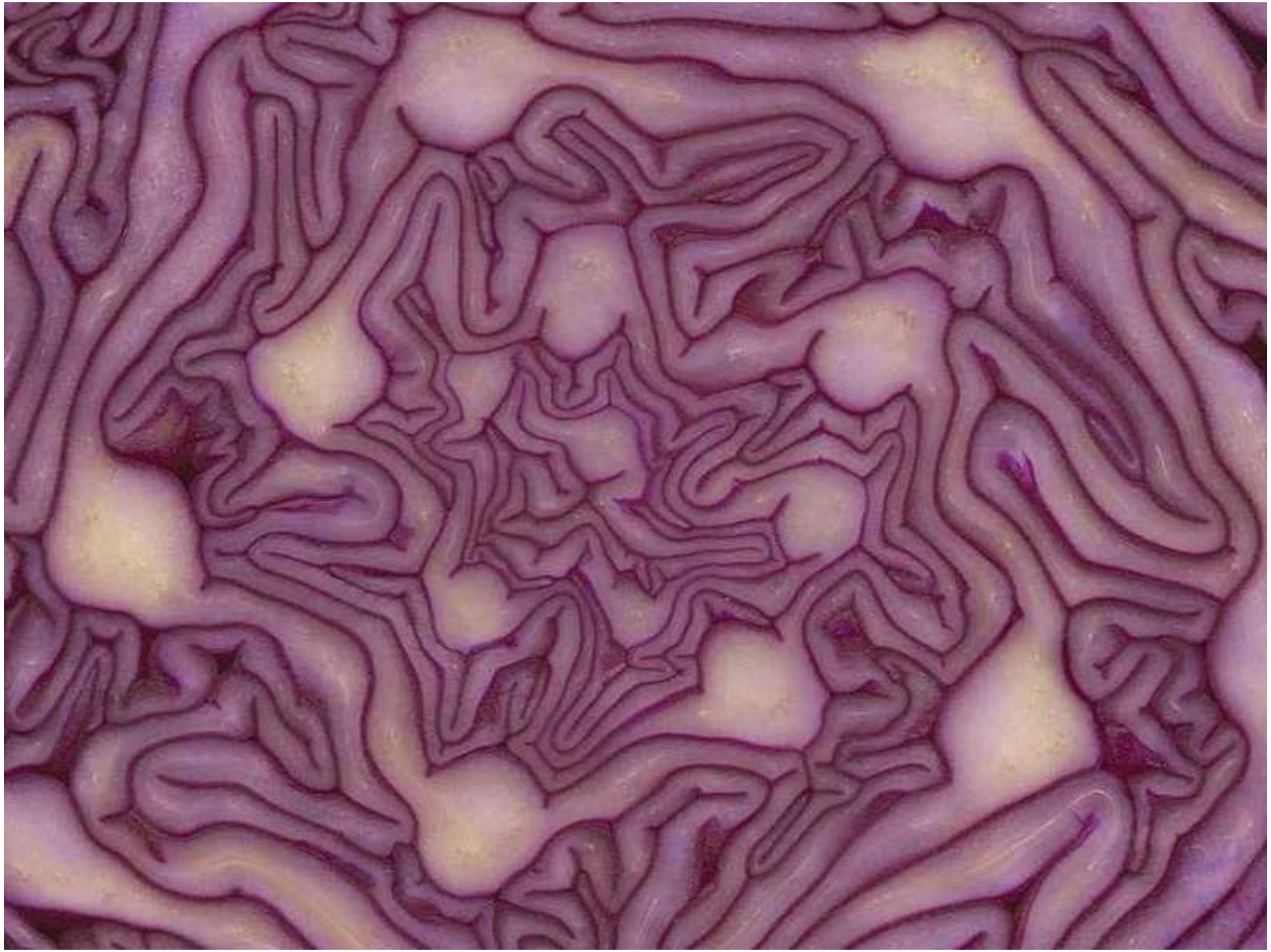


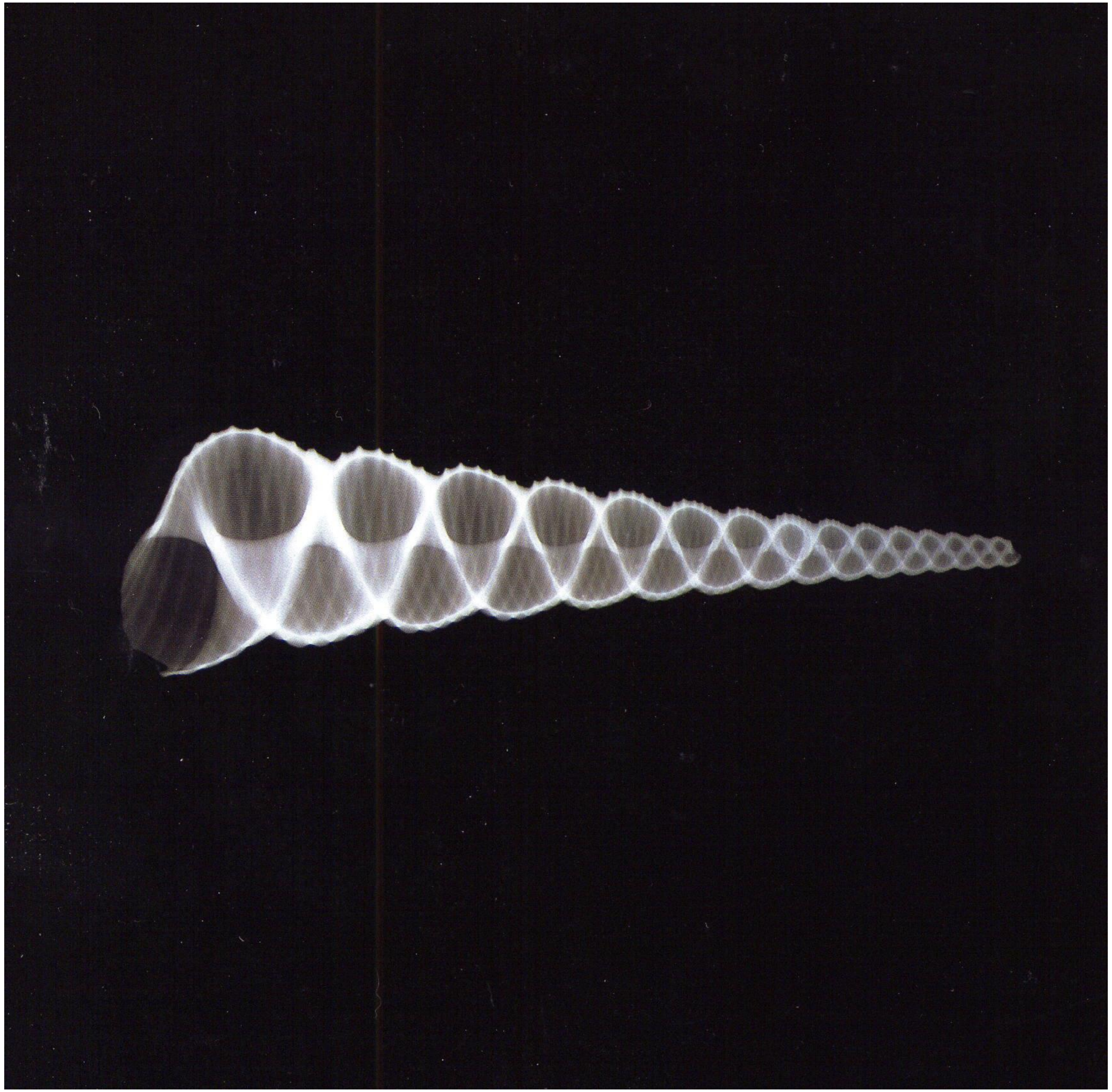


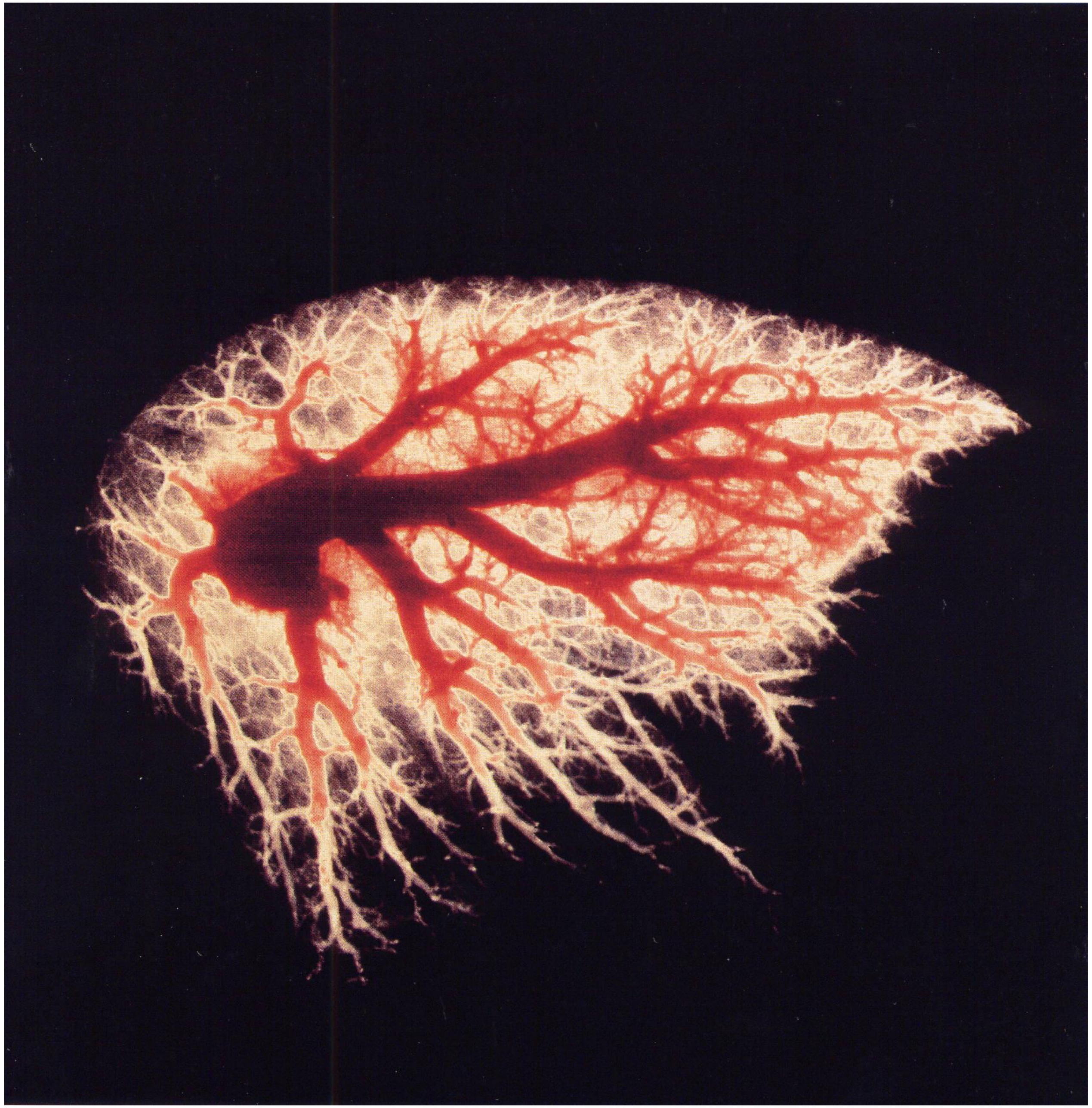

Messier 51
Cosmic hurricane
Courtesy NOAO
www.fvalk.com

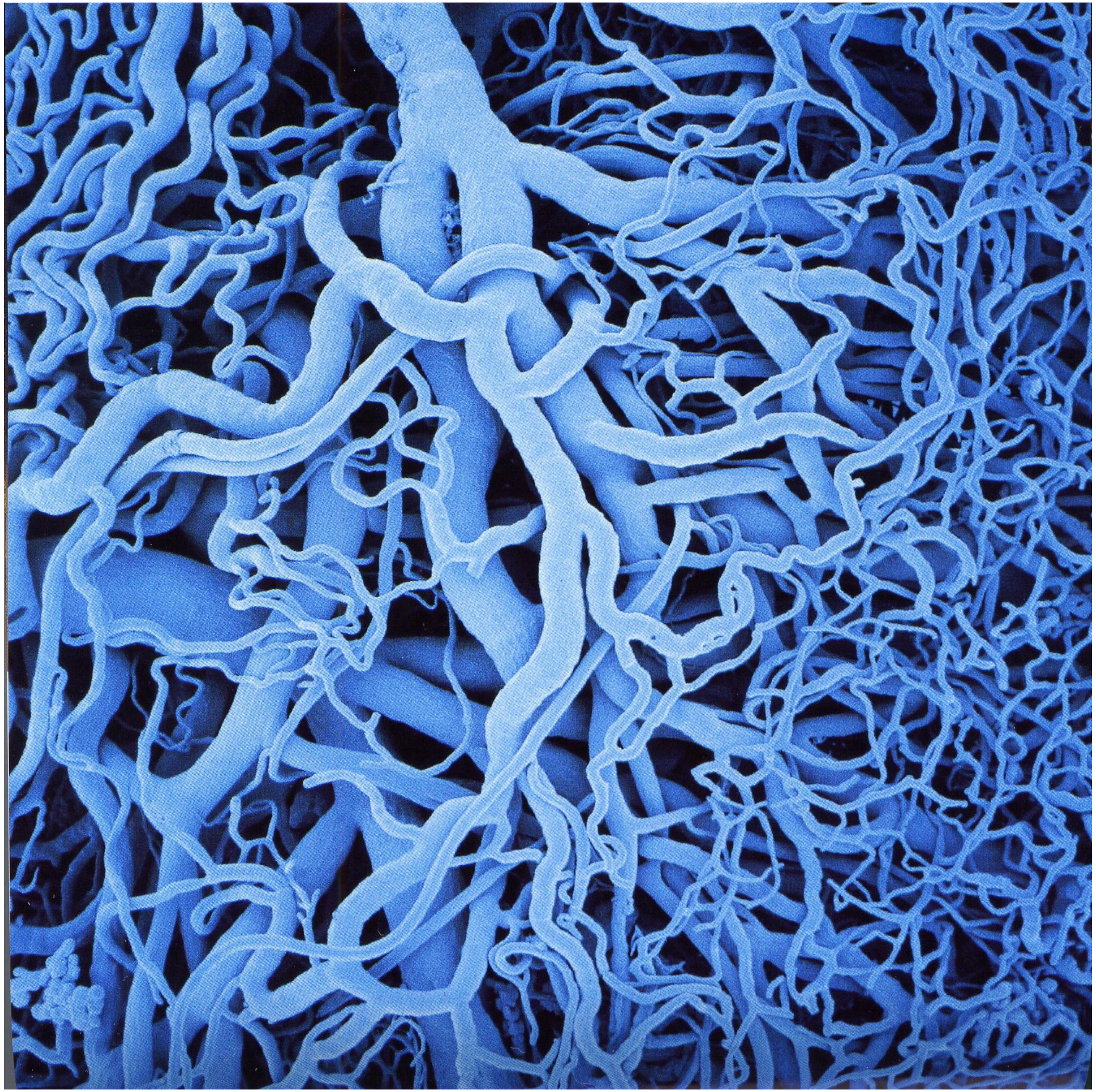


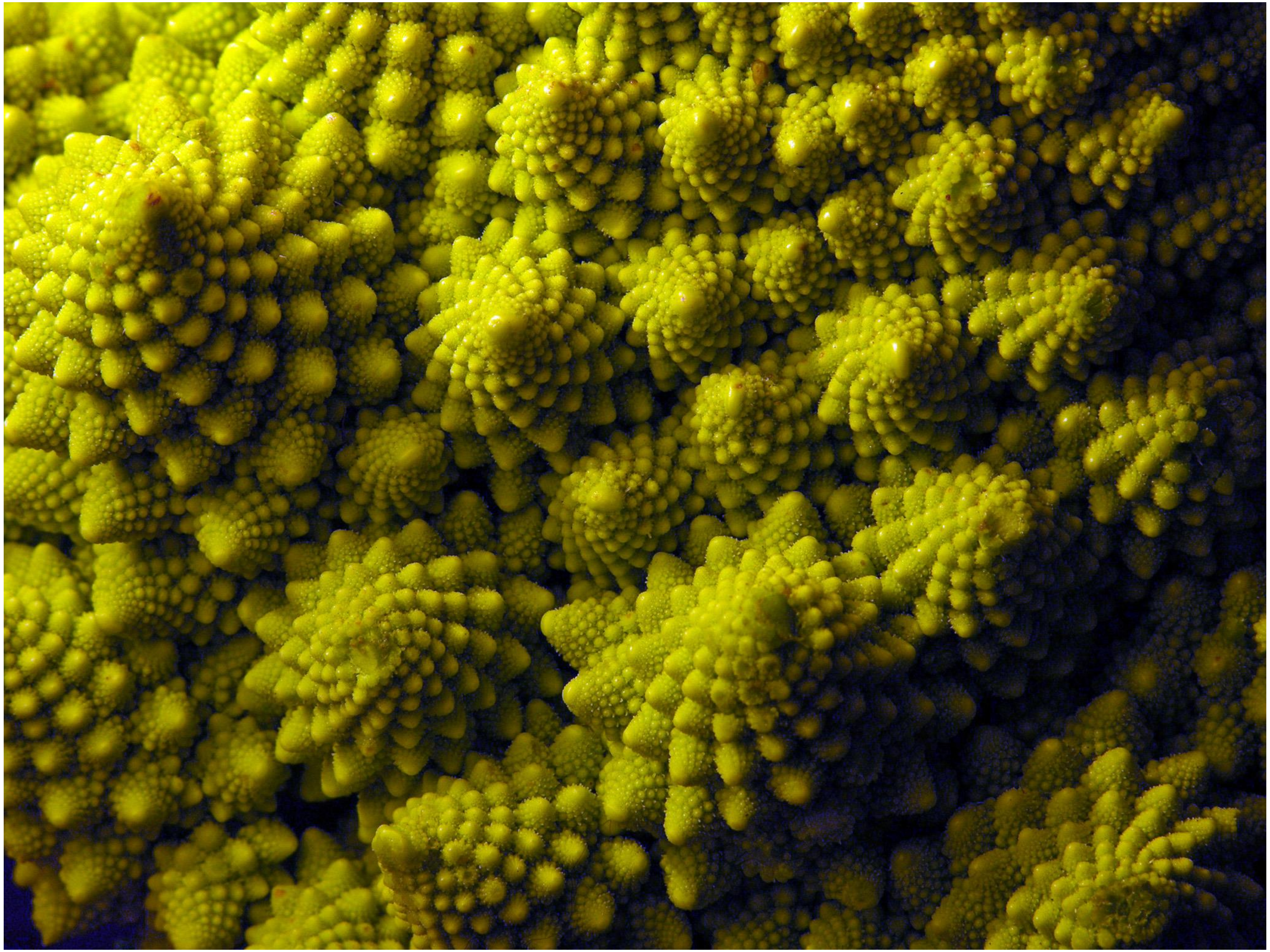

Counter-
clockwise
Clockwise

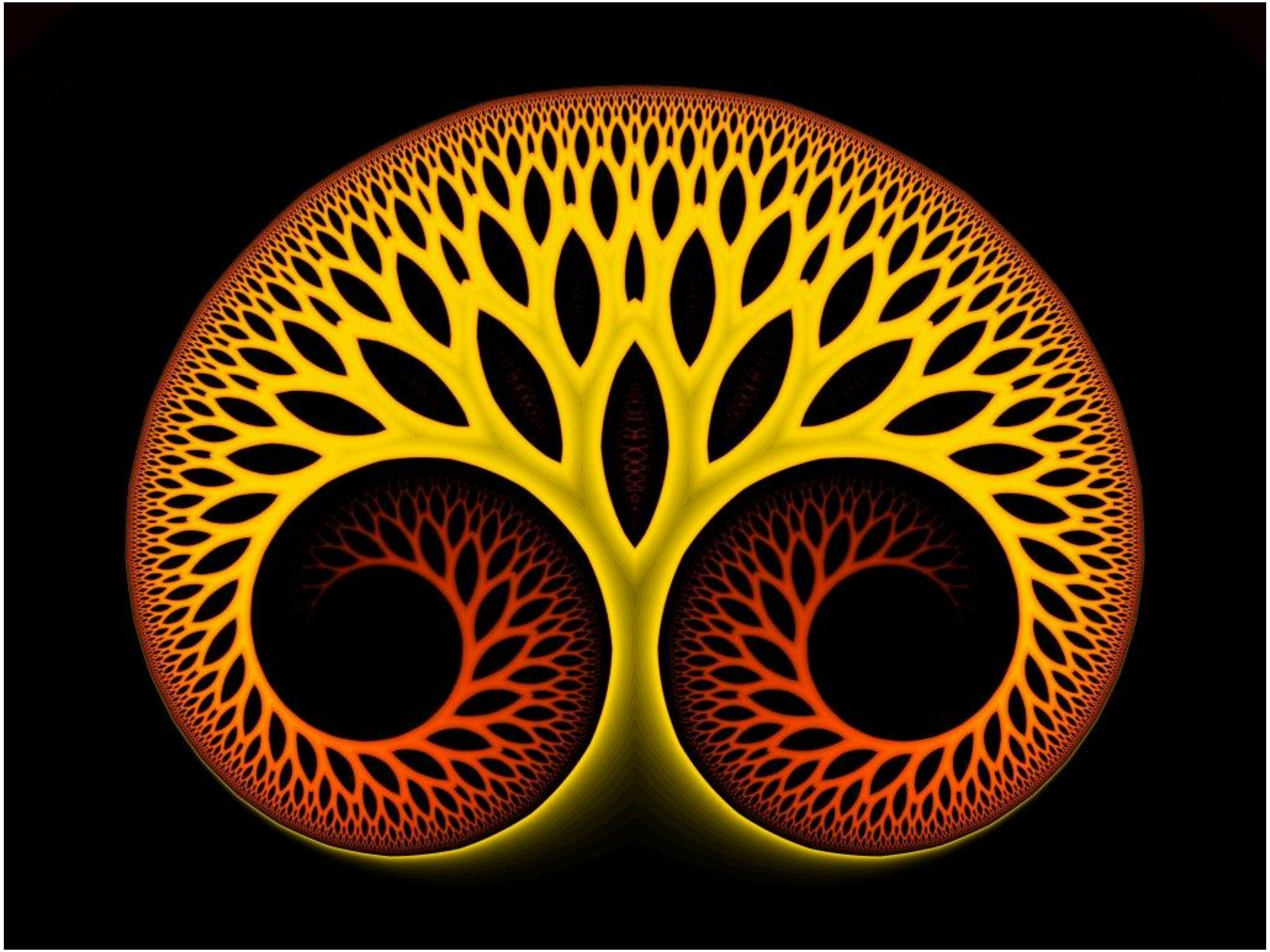


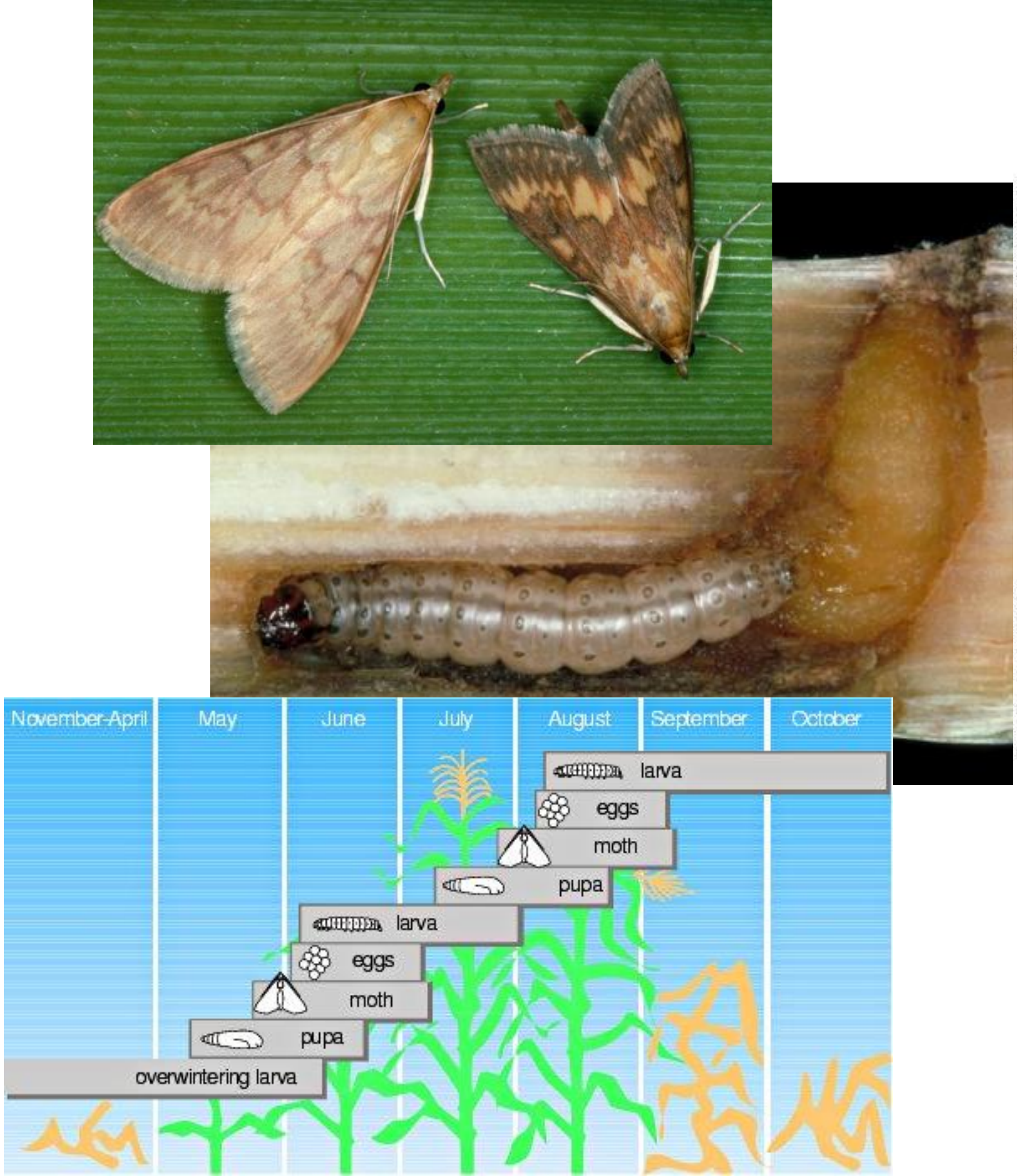


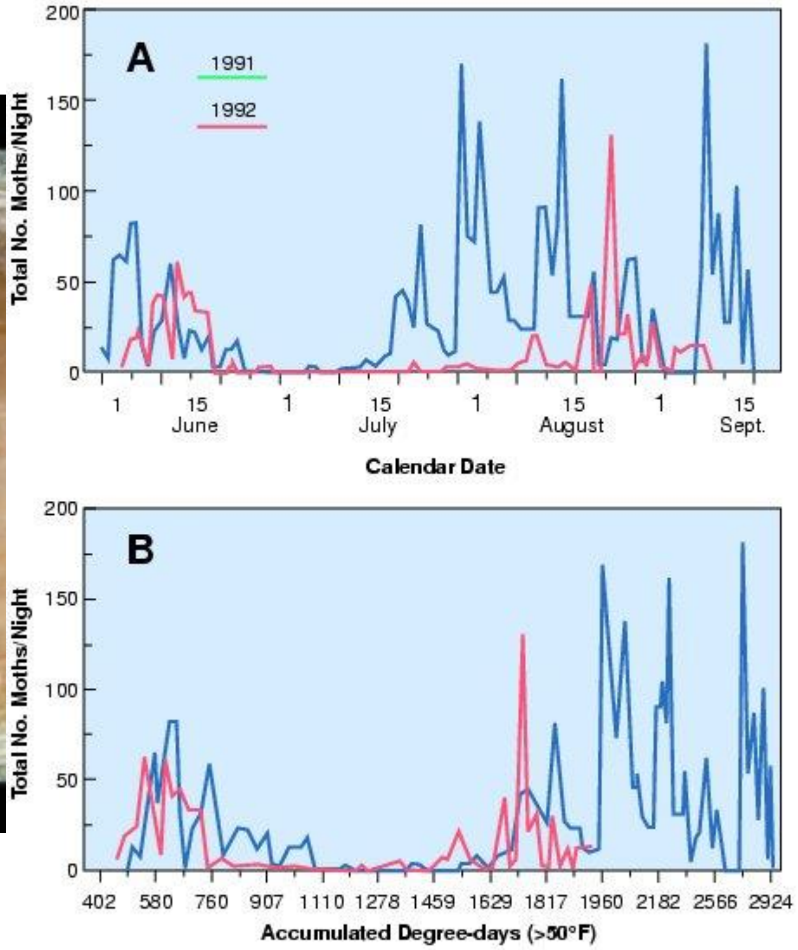






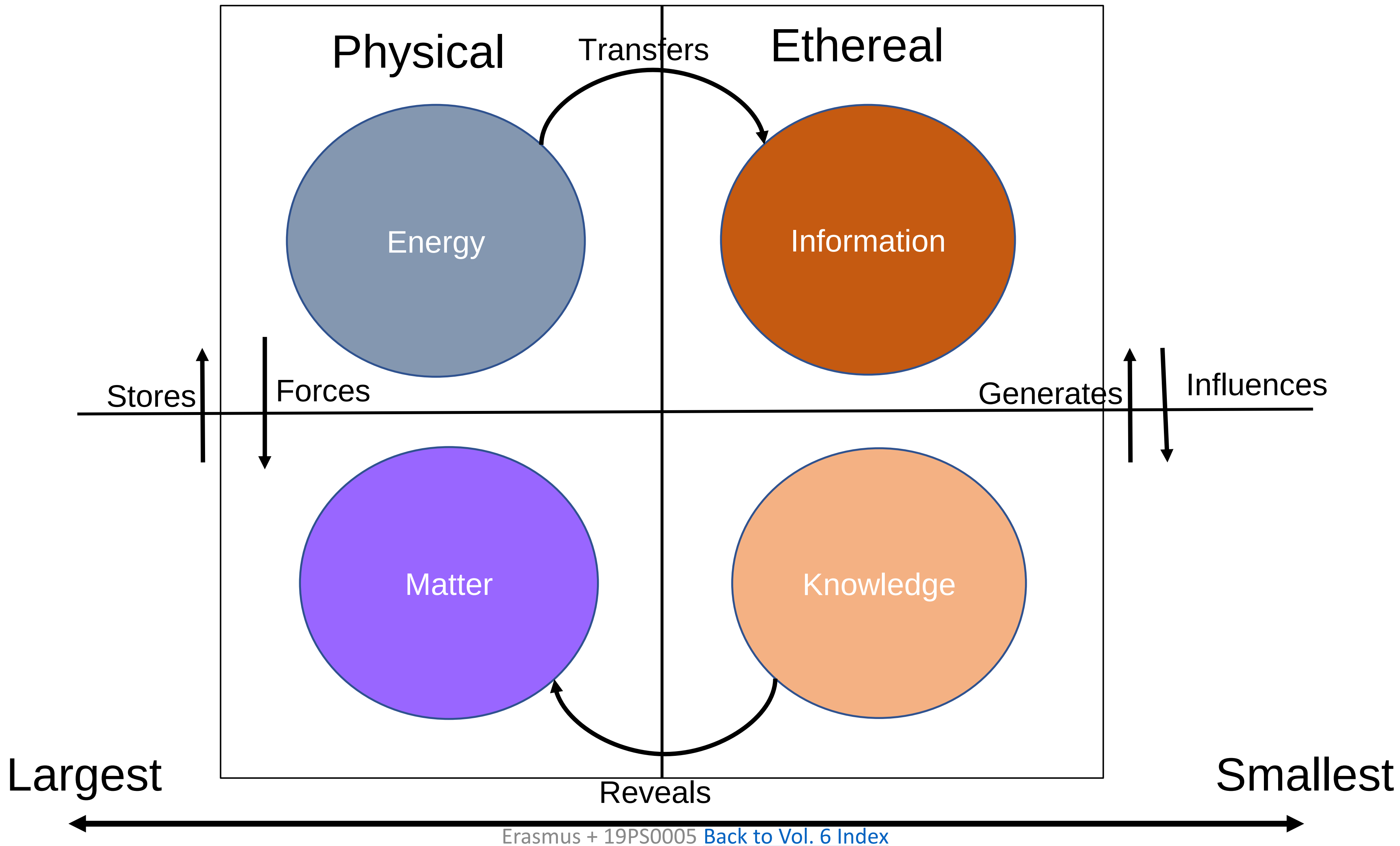






European corn borer moth flights during two years, near Rosemount, Minnesota. Figure A illustrates seasonal variation on a calendar timescale; Figure B shows synchrony based on a degree-day timescale (W. D. Hutchison).

System Science - Ontological Perspective



Bibliography/references

References from Web:

- https://www.smithsonianmag.com/science-nature/science-behind-natures-patterns-180959033/
- https://www.smithsonianmag.com/science-nature/mysterious-fairy-circles-have-been-found-western-australia-180958407/
- https://en.wikipedia.org/wiki/Patterns_in_nature#Types_of_pattern
- https://www.slideshare.net/keithdjohnson2/pattern-understanding-67749914?qid=7ab4b3f5-006a-4c09-85c3-f801606074a1&v=&b=&from_search=6

References:

- Mitchell, W. J.: The logic of architecture – Design, computation, and cognition, MIT Press, London, 1990
- Knight, T.W.: Transformations in design – A formal approach to stylistic change and innovation in the visual arts, Cambridge University Press, New York, 1994
- Hess, W.N., Nervous system of the earthworm, lumbricus terrestris L., Journal of Morphology, Volume 40, Issue 2, P. 235–259, 1925
- Ball P., Patterns in Nature: Why the Natural World Looks the Way It Does, 2016
- A Pattern Language
- The Web of Life
- A Pattern Language of Sustainability, Tippett, J, BA Thesis at Lancaster University - unpublished, 1994, Holocene@juno.com
- Fractals, The Patterns of Chaos, Discovering a New Aesthetic of Art, Science and Nature, Briggs, K., Thames&Hudson, 1992
- The Tree of Knowledge, Maturana, H. & Varela, F., Shambala 1987
- Permaculture - a Designer’s Manual - Mollison, Bill - Tagari Publications
- Sacred Geometry

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Volume 7 – Student Tasks

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PERMAQUIZ

1 - Permaculture is:

- a. A technique for sustainable agriculture
- b. An approach to the design of sustainable human systems
- c. A set of techniques for sustainable agriculture

2 – I can talk about the application of Permaculture when ...

- a. I adopt sustainable agriculture techniques such as the synergistic vegetable garden, etc.
- b. I don't use pesticides
- c. the crops are organized and managed according to the design principles

3 - A model or pattern in permaculture is

- a. an appropriate scale representation of a natural environment
- b. something found in nature that can be adopted in the design to structure the structure and functioning of a system
- c. a natural object with a particular shape that I can reproduce in the system

PERMAQUIZ cont ...

4 - Zones and sectors is:

- a. a permaculture design method
- b. a method for representing areas with different intended uses on a map
- c. a way to do a context analysis of a site

5 - Zones are areas of the site where it is identified:

- a. the energy available on site
- b. the energy flows that pass through the system
- c. crop planning for the site

6- The sectors represent

- a. portions of land where it is possible to do certain activities
- b. the energy flows that pass through the system
- c. the energy available on site in the system

PERMAQUIZ cont. ...

7 - On a project site ...

- a. all zones must always be identified, from zone 0 to zone V
- b. only some areas may be identified while others may not be present
- c. the identified zones necessarily have a configuration of concentric circles in which the innermost part is zone 0 and the outermost part is zone V

8 - The identification of the areas

- a. it depends a lot on the morphology of the area
- b. it can be done independently of the morphology, because it is a planimetric representation
- c. it is linked to the morphology, since the attribution of the areas is made on the basis of the shares of the land

9 - Observation of a site where you plan ...:

- a. it is a design method of wich cannot be done without
- b. it is something that is strongly recommended if there is the possibility to do, but it can be replaced by one of the other design methods
- c. it can be free or thematic

PERMAQUIZ cont. ...

10 - The guilds are:

- a. the association of different species that can be found in nature, grouped around a central element, with the function of mutual aid in the development and mitigation of adversities.
- b. groups of crops typical of a certain place
- c. elements observable in a site from which one can take inspiration for the design.

11 - The analysis of the elements is used ...:

- a. to understand why a certain element of the system presents problems
- b. to understand what contribution a given element can provide to the system
- c. to make a time schedule of the project activities to be implemented on a site

12 - The products or outputs of the elements constitute a resource for the system ...

- a. in any case, since they are goods or services that constitute a kind of capital of the system
- b. only when the manager gives it the resource value
- c. only if used constructively, otherwise they can become polluting or involve extra work

PERMAQUIZ cont. ...

13 - The relative positioning of the elements ...

- a. it is a way of representing on the site map the arrangement of the elements that are related to each other
- b. derives from functional analysis, which suggests how elements can be arranged in space in favor of useful relationships
- c. it allows to identify an optimal spatial distribution of the elements

14 - The scale of permanence

- a. it is a way of approaching the design of a site
- b. it is a way to approach the preliminary analysis of a site
- c. it is both, a way to approach both the preliminary analysis and the design of a site.

15 - The scale of permanence

- a. indicates the priority with which it is appropriate to consider the elements of the system, on the basis of their relative influence
- b. it serves as a tool for understanding which elements of a system are more stable or "permanent" than others
- c. it refers only to elements that within a system can be considered "permanent" or long-lasting

PERMAQUIZ cont. …

16 - Among the elements represented in the permanence scale

- a. The climate is the least affected
- b. the soil comes immediately after the climate as it takes a lot of time and energy before its modification
- c. the last four are those on which a more thorough design is made

17 - The following information can be obtained from the permanence scale

- a. as part of a large project, we can take care of the recovery of soil fertility in a non-priority way
- b. when approaching the design of a site, it is advisable to first work on the general layout of water and roads, and then worry about the arrangement of structures, fences and crops later.
- c. when approaching the design of a site, it makes no sense to think about interventions to modify the climate and morphology

PERMAQUIZ CORRECT ANSWERS

- 1 - b
- 2 – c
- 3 - b
- 4 – a,c
- 5 – a
- 6 – b
- 7 – b
- 8 – a
- 9 – a,c
- 10 – a,c
- 11 – b
- 12 – c
- 13 – b,c
- 14 – c
- 15 – a
- 16 – a
- 17 – a,b

Tasks Volume 2 – Methods of design

Chapter/TOPIC	Methods and design
Title	Forest pattern
Objective	Observe, recognize, decode, and use the forest pattern
Permaculture Principles	• Observe and Replicate Natural Patterns
Category	Fieldwork and/or deskwork
Group or Individual	Individual or group
Duration	2 h
Location	Outdoor and/or indoor
Description (as detailed as possible)	1. Observe a forest, according to the following points of view: a) Top view of the horizontal plane (aerial photo) b) View from the below on the horizontal plane (imagining yourself lying on the ground and looking towards the sky) c) Vertical prospectus (view from outside the forest) d) Vertical section e) Vision of the ground from above, but from inside the woods Vertical section of the litter and soil profile 2. Identify the essential and peculiar characteristics that described the forest pattern 3. Understand and describe how to use this pattern in cultivation techniques
Assessment criteria	Ability to observe, describe and decode patterns Recognize and establish relationships Knowing how to make logical connections Critically integrate information from different channels Creative ability to rework the pattern in the design
resources	Photos of forest in different views and perspectives

Tasks Volume 3 – Permaculture and the climate change challenge

1. Whole Systems Design Thinking

<table>
<tr><th colspan="3">Learning Activities (Use https://miro.com/ or similar to compile your Activities)</th></tr>
<tr><th>Sub-Section</th><th>Individual Student Activities</th><th>Group Student Activities</th></tr>
<tr><td>1.1 Context</td><td>What is the Ecological Footprint for your country, and if possible, your region, and briefly discuss your findings</td><td rowspan="4">Establish groups of 3 or 4 students to debate with other groups the pros and cons in the following hypothetical development options of a major investor:
• Invest in a cargo shipping venture, comprising, either a small fleet of large ships, or, a large fleet of small ships.
• Invest in a food production venture with value chain logistics, packshed and distribution, comprising, either one large regional central hub, or, several smaller district hubs.
• Invest in an energy production and distribution venture, comprising, either one large regional central power plant with a single source of energy, or, several smaller power plants tailored to suit local multiple energy sources..

For each option, consider debating aspects such as, infrastructure, logistics, resources, economy, jobs, risk and resilience.</td></tr>
<tr><td>1.2 Whole Systems Design Approaches</td><td>Explore your neighbourhood or town / city and identify an activity that is, (1) linear and (2) cyclical.
Outline how the above linear activity can become more sustainable through a cyclical approach.</td></tr>
<tr><td>1.3 Whole Systems Design Teams</td><td>Is your foundation study field setting you up as an Expert, a Generalist, or both (“T-shaped”)?
Explain what skills set you wish to attain to advance your career.</td></tr>
<tr><td>1.4 Climate Change mitigation and adaptation policies and strategies</td><td>Explore your neighbourhood or town / city and describe at least one activity in each of the three interrelated components that is being done, and another which ought to be urgently considered.</td></tr>
<tr><td></td><td colspan="2">Educators to set up small groups of 4 to 5 students to briefly share and reflect on their individual activities in order to extend the overall lessons.</td></tr>
</table>

2. Permaculture solutions for Agriculture to mitigate to Climate Change

Learning Activities (Use https://miro.com/ or similar to compile your Activities)		
Sub-Section	**Individual Student Activities**	**Group Student Activities**
2.1 Context	What is the Ecological Footprint of the Agricultural Sector for your country, as well as, the Organic Sector percentage, and briefly discuss your findings.	In groups of 3 or 4 students, identify a rural farming area of 1 to 5 hectares, for a team design project wherein at least one student has reasonable access for site visit(s). Capture the orthophoto map from Google Earth Pro, including contours (1 metre levels) and any other relevant and easily accessible information. Follow the Scale of Permanence design sequence but focus on a broad concept design framework that integrates the following aspects: • Restoration of gullies and riparian zones • Keyline swales with detention ponds and various dams • Access roads and/or footpaths • Appropriate forest-belts (indicate some key nitrogen fixing tree species for all forest levels) The above provides the regenerative framework for your concept design. Thereafter, identify the microclimate areas within this framework and delineate potential land uses for the following: • Buildings, including residential and farm facilities • Seasonal crops • Agroforestry / orchards • Wilderness
2.2 Climate Change solutions for application of Design Systems	Identify an eroded water course with a limited or non-existent riparian zone in your neighbourhood and show on an orthophoto map from Google Earth Pro, with contours (1 metre levels). Annotate the appropriate restoration process for this water course and riparian zone on the orthophoto map.	
	Practice setting out swales on contour with an A-Frame and a Water Level. Practice desktop Keyline design for a rainwater harvesting plan from an orthophoto map.	
	Identify the Köppen–Geiger climate classification system for your region. Plan a typical forest-belt for your region using the template examples provided.	
	Identify the dominant use of farm equipment for land preparation in your region (eg. ploughing, harrowing, levelling). Interview a farmer or two and ask them to explain their methodology for land preparation and ask them if they have considered any more sustainable methodologies, such as Limited-Till.	
2.3 Climate Change solutions for application of Design Components	Find a sample of mycelium rich rotting wood or soil in a nearby forest. Research a methodology for enhancing mycelium into an orchard or agroforestry plot.	
	Make a list of ingredients for a small bowl size mix of seedballs infused with flower seeds designed to attract pollinators to a vegetable garden. Make the seedballs, allow to dry, retain a few in a sample pot, disperse the rest, and monitor progress in the sample and the garden where dispersed.	
2.4 Integrated Climate Change solutions	From the above table, extrapolate the potential CO_2 sequestration for your country and region, then briefly outlines your findings.	
	Educators to set up small groups of 4 to 5 students to briefly share and reflect on their individual activities in order to extend the overall lessons.	

3. Permaculture solutions for the Built Environment to mitigate to Climate Change

Learning Activities (Use https://miro.com/ or similar to compile your Activities)		
Sub-Section	**Individual Student Activities**	**Group Student Activities**
3.1 Context	What is the Ecological Footprint of the Built Environment for your country, and briefly discuss your findings.	In groups of 3 or 4 students, identify an area comprising a suburb, town or village (the public realm), with at least one public building, for a team design project wherein at least one student is resident. Capture the orthophoto map from Google Earth Pro, including contours (1 metre levels) and any other relevant and easily accessible information.
3.2 Sustainable Building Design Strategies (3-D)	Set up a template based upon the Sustainable Building Design Strategies for each component / sub-component, for a basic assessment (Score of 1 to 5) of your own home. Undertake a basic assessment (Score your opinion out of 5) for each component / sub-component . In your opinion, outline which component is the most appropriate and value for money retrofit investment for your home.	Set up a template based upon the Sustainable Building Design Strategies for each component / sub-component, for a basic assessment (Score of 1 to 5) that can be undertaken for a significant public building / cluster, such as, municipal offices, town hall, school, etc. Undertake a basic assessment (Score your opinion out of 5) for each component / sub-component. In accordance with the basic assessment, outline the proposed sustainable design solutions and rank indicatively in terms of value for money retrofit investment of the public building.
3.3 Sustainable Spatial Strategies	Set up a template based upon the Sustainable Spatial Strategies for each component / sub-component, for a basic assessment (Score of 1 to 5) that can be undertaken for your own suburb, town or village. Undertake a basic assessment (Score your opinion out of 5) for each component / sub-component. In your opinion, outline which component is the most appropriate and value for money investment for your suburb, town or village.	Set up a template based upon the Sustainable Spatial Strategies for each component / sub-component, for a basic assessment (Score of 1 to 5) that can be undertaken for the suburb, town or village. Undertake a basic assessment (Score your opinion out of 5) for each component / sub-component. In accordance with the basic assessment, outline the proposed sustainable design solutions on an orthophoto map and rank indicatively in terms of value for money retrofit investment of the public realm.
3.4 Sustainable Design Integration		Undertake a very broad desktop concept design on the Miro Board, with insights from the resident team member, for how to link and integrate the 3-D and 2-D basic assessment using a Permaculture design process for the area around the public facility.
	Educators to set up small groups of 4 to 5 students to briefly share and reflect on their individual activities in order to extend the overall lessons.	

Tasks Volume 4 – Soil, water and biogeographical regions

Think and task questions

Think questions

What useful informations have you learnt from this chapter?

Task questions

1. Choose a soil, undistrubed or cultivated, and perform some textural tests on the soil. Write a small essay (max 3 pages) that describes the soil:

a) What is the texture of the soil?

b) What is the history of the soil? Could it be polluted? What have been the agricultural practices?

c) Which informations can you find on maps (geological, hydrological, ...) about this location?

2. Make a soil profile and describe it in max 3 pages. With a spade, make a vertical slide in the ground that goes as deep as 70cm if possible.

a) Which different horizons (colors of soil) can you differentiate? Can you distinguish soil aggregates? Do you notice any particular smell?

b) Which type of vegetation grows spontaneously in that zone?

c) How deep does the rooting of the surrounding vegetation go? Do you find a compaction layer while excavating soil?

d) [facultative] Perform an earthworm count.

Tasks Volume 5 – Science and natural laws

Title	Natural patterns: observation and application
Objective	Recognize patterns, understand their functions, and know how to use them in the design
Permaculture Principles	• Observe and Replicate Natural Patterns • The only limit we have is imagination
Category	Fieldwork and deskwork
Group or Individual	Individual or group
Duration	2h
Location	Outdoor into the nature and indoor
Description (as detailed as possible)	1. Go outside and observe the patterns of natural forms 2. Draw by copying from the real some natural forms 3.Describe them, trying to understand their essential and typical characteristics 4. Investigate the relationship between forms and functions 5. Describe and draw how and why such patterns can be copied and applied in the permaculture design
Assessment criteria	Ability to observe, describe natural objects Ability to read shapes and make logical connections Creative ability to rework to solve new problems
resources	Drawing sheets, clipboard, pencils for drawing.

Tasks Volume 6 – Pattern understanding

Chapter/TOPIC	Pattern understanding
Title	Exploring a model
Objective	Understand how a specific model works.Imagine the application of a model to a specific case.
Permaculture Principles	Observ and interact
Category	Research activity
Group or Individual	Mostly individual, in a group context.
Duration	About 90 minutes in total in the classroom in addition to the time to carry out the research.
Location	Indoor and outdoor.
Description (as detailed as possible)	For the site or one of the sites where the observation activity was carried out, each participant chooses a representative element, which could be evaluated as a model for the design of the same site. This element can be a plant (for example the plant present mainly, or the one that best adapts to the extreme conditions of the place), an animal (for example a bird that clearly contributes to the reproduction of a given plant species), a natural process or human (e.g. the development in succession of vegetation, transhumance as a rotation in the use of portions of land, etc.) or any other element that is considered significant for that given place. Once the element has been chosen, each participant will carry out a more in-depth research on it, using all available means (internet, scientific books, direct observation of the element in all its parts if possible, consultation of specialists and experts , etc.).The criteria listed below may serve as a guideline for research, if applicable: a) macro and micro shape; b) functions of the individual parts of the element; c) strategies of survival and adaptation to the place; d) operating mode; and e) flows (of matter and energy) For the choice of the model, a 15-20 minute observation walk on the site is required, which students can do individually in the group context or on their own accord, depending on the site in question. The time to carry out the research will be assigned to the teacher according to the organization of the lessons, a few days could be allowed. As a product of the research, students will create a form for their model which can be digital (in pdf, ppt, word or other format) or paper (A4 sheets, posters, etc.), and which can include drawings, photos, texts, video, more. Students can also collect the element chosen as a model from the site, if applicable (e.g. a plant, a rock, etc.). At the end of the search, the products of each will be shared in the group in the following way:1) groups of 5-6 students are created, each of whom has about 5 minutes to present their work(25-30 min).2) At the end of the previous phase, the group meets and through a discussion led by the teacher we try to imagine how these models could be applied in specific cases (e.g. the spiral model for a vegetable garden to obtain different exposure to sunlight, the model of a pioneer plant to structure a project characterized by resilience, etc.)(30 min).
Assessment criteria	Degree of depth and quality of the research work (also with reference to the criteria listed above), contributions of the final discussion.
Resources	Each participant will procure the material they choose to use for research.For sharing in the classroom, computers and a video projector may be needed.

Tasks Volume 7 – Student Tasks

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The reflective diary or reflective journal.

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A useful tool for assessment throughout the course is the reflective diary or reflective journal. The use of reflective diaries has at least four major advantages:

- It is based on continuous assessment. Students start the reflective diary at the beginning of the course and hand it over at the end of the course. They are encouraged as a minimum to put an entry after every lecture, fieldwork, or practical. However, they can put an entry any time they reflect on something that is related to the outcomes of the course.
- It allows students to measure their own learning against the learning outcomes but also to see and monitor their own development and how their ideas changed with time. They are able to capture their own personal development and growth.
- It allows not only for a description of their learning but for critical reflection on their learning. It provides a space for them to ask questions, express their doubts, and write about their hopes. It allows them to develop their own identity as change makers.
- It allows students to use not only text but any other medium they feel comfortable in. They can write poetry, sketch, paint and include photographs.

For those not so familiar with a reflective dairy, you may want to look at the following:

- https://penzu.com/how-to-write-a-reflective-journal
- https://www.ivoryresearch.com/library/other-articles/reflective-logs-and-reflective-diaries/
- https://wikieducator.org/Reflective_journals
- https://www.monash.edu/rlo/assignment-samples/education/education-reflective-writing

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