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The orchard as a complex system: a Permaculture Design Model

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Abstract

Permaculture is an ethical and informed methodological approach to designing and managing productive and sustainable complex systems, that mimics the patterns of natural ecosystems. Orchards, like agricultural ecosystems, are complex systems typical of the living world that can be understood through a holistic approach.

The aim of this contribution is to analyse the complex orchard system through one of the tools of permaculture design: functional analysis. This tool, in line with and in support of the European directive on organic production, allows for the improvement of orchard management in all its aspects and has proven to be suitable for integrating and "systemising" specialist experimental knowledge. Functional analysis can therefore be a useful tool in both the planting and management phases of an 'organic' orchard, highlighting the strengths and critical elements of the system, and defining goals for further improvement.

Keywords: permaculture, ecosystem, farm design, organic orchard

Introduction

Orchards, like natural habitats or organisms, are complex systems typical of the living world, and thus also of agricultural ecosystems. They can be understood in their entirety and distinctiveness through a holistic approach able to identify the interconnections that are formed when the individual elements mesh together. Permaculture is an ethical and informed methodological approach to designing and managing productive and sustainable complex systems that mimics the patterns of natural ecosystems. Its focus is on the design of relationships that serve to realise a model that is strongly based towards self-sustainability. Concerning its use in organic farming, we can observe that the three ethical principles on which it is based, people care, earth care and future care/fair share, as well as its design principles, are perfectly consistent with the objectives and general principles defined in Articles 4 and 5 of the current legislation for organic production, Regulation (EU) 2018/848.

Another aspect concerns the fundamental role of sector-based and specialised scientific research in guiding the agronomic choices of the organic orchardist. However, it is becoming increasingly evident that it is necessary to optimise the results of this knowledge in a more systematic fashion through specific models, that can help us improve the management of all aspects of organic orchards (agronomic, economic, ecological, consumer welfare and, of course, farmer welfare).

Material and Methods

The aim of this contribution is to begin analysing the complex orchard system through one of the tools of permaculture design: functional analysis. In our case, the farm in its distinctiveness represents a complex system, i.e. an organism formed in its turn by other systems, all interconnected. Using this type of analysis, for each element of the 'farm'

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system, all the inputs necessary for it to perform certain functions and all the outputs derived from them are identified. The outputs represent potential resources when they are used productively by other elements of the system but become pollutants otherwise. Inputs or material needs should be supplied by other parts of the system; if this is not the case, external energy must be brought in, in the form of additional labour or extra resources (Mollison, 1988). This tool was designed to understand and decipher existing connections, to create new and beneficial ones by introducing additional elements and installing them spatially close to the parts we want to connect.

First, it was necessary to define the type and characteristics of the element under consideration, or rather, the functions we want it to perform within a farm. We thus focused on an orchard capable of performing functions in compliance with the three permaculture ethics and their design principles, as well as consistent with Articles 4 and 5 of Regulation (EU). 2018/848 (Table 1).

Table 1: Functions of an orchard under permaculture and the ethical principles they satisfy.

Functions	Ethical principle~~s~~
Provide an income for a farming family (farmer welfare)	People care
Produce fruit with high nutritional value (consumer welfare)	People care
Maximum self-sustainability with minimum use of technical means	Earth care
Sustainable, economic and environmental vision in the long term	Fair share/Future care

Next, the connections of an orchard are identified, listing their inputs and outputs (Table 2).

Table 2: Functional analysis of an organic orchard.

INPUTS	OUTPUTS
Soil	Fruits
Nutrients	Wood
Land biodiversity (macro and micro)	Leaves
Water	Seeds
Rootstocks	Pollen
Varieties	Habitat
Plant biodiversity	Landscape
Pollen and pollination	Shade
Pruning	Windbreak
Pathogens/parasites management	
Herbaceous management/soil cover	
Wildlife management	
Ventilation and lighting	

Results

It should be emphasised that in permaculture the farmer must consider the type of system he wants to create, based on the natural primary forest succession. An orchard, in this evolutionary scheme, is considered a system that has the structure of a young forest of pioneer plants. This process takes a few decades in nature, considering both the aboveground and the soil. The objective is therefore to reduce the time by means of a supply of organic substances together with green manures, transitional groundcover, and mulching and wood composting, to stimulate microbiology and accelerate fungal dominance in order to obtain a good humus layer and to encourage the presence of mycorrhizal species. To meet the plant's nutritional needs and soil fertility, in addition to what has already been described, other herbaceous plants, shrubs or small trees (single plants, hedges, copses, etc.) that are nitrogen-fixing and dynamic accumulators of nutrients will be introduced. This aspect also contributes to providing the plant biodiversity required by the system. As far as water is concerned, the aim of permaculture applied to organic farming is to limit irrigation input to what is necessary. The strategy is to improve water retention capacity through the creation of adequate soil structure and organic matter and to favour more vigorous rootstocks capable of exploring deeper soil strata. Varying the degree of pruning, in the autumn-winter period, but not only, maintains the shape of the trees and at the same time leads to a rapid entry into fruiting. In the case of apple trees, clonal rootstocks are used such as M111, (which is also quite resistant to Fire Blight) and GC 11. For all fruit species, we can use seedlings that have a deeper taproot and can also result from direct sowing in the field, or they can be taken from wild plants in the undergrowth which generally have a lower vigour and induce faster fruiting.

As far as the choice of variety is concerned, an attempt is made to make the maximum use of interspecific agro-biodiversity, precisely to exploit the degree of resistance of each individual genotype. Hence, polyculture and multi-varietal orchards with predominantly local varieties are chosen from among those resistant to the most important pathogens, such as apple scab (Buscaroli C., 2022), peach leaf curl, apricot brown rot and plum bacterial spot. In the case of apple, there are other recent varieties with monogenic resistances (Rvi6, Rvi5, Rvi10) and old varieties with polygenic resistances (*Bella di Boskoop, Reinette Ananas, Renetta grigia di Torriana*). The aim is to have as extended a ripening calendar as possible to meet the needs of direct sales and nested market, but also to provide fruit with a high nutraceutical level. Indeed, it has been shown that old varieties have a higher vitamin C (Dalla Valle *et al*., 2007) and polyphenol (Costa *et al*.,2020) content than new breeding varieties. Establishing multi-varietal orchards also allows a large circulation of pollen. Recent research (Alessandri S. et al., 2023) has shown that the S alleles of local and ancient apple varieties are very different from each other and from more recent varieties, such as those resistant to scab. The use of grassland, in which leguminous and other entomophilous pollinating plant families are present, also favours the entry of bees into the system.

Experience shows that it may be necessary to provide an external supply of green manure plants only in the pre-transplant phase. Afterwards, the soil must be kept covered and in a few years an equilibrium situation is formed in the inter-row with about a third of nitrogen-fixing species, which makes it possible to eliminate nitrogen fertilisation with external inputs. The input of organic substances produced within the farm system on the other hand induces the development of the microbiology necessary to supply the mineralised nutrients available to the plants, which can also be verified by monitoring the biological fertility indices. Subsequently, the soil cover is maintained by mulching the mowings in the inter-row, using leguminous plants with limited growth (*Trifolium subterraneum* and *T. michelianhun*) and by associating the fruit plants with other species that have a restraining effect on the weeds.

Pests, pathogens, and wild animals are inputs that we must try to introduce into the system below the damage threshold. Therefore, first of all resistant varieties with different types of resistance, mainly polygenic are utilised. And then other elements are introduced within the orchard or adjacent to it, such as the creation of hedges with different and spontaneous species so as to encourage beneficial connections with antagonistic species, the creation of habitats for birds, bats, reptiles and amphibians, the maintenance of unmowed grass in the field or at least in alternate rows, the insertion of disposable or attractive crops. Only as a last resort, anti-intrusion nets are introduced. An extensive bibliographic and experimental literature exists on the plant species to be introduced in our region and the strategies to be adopted to manage biodiversity and the multifunctional relationships between plants and insects, in a complex agroecosystem (Burgio *et al*., 2021). Insect nets, on the other hand, do not interact in the system cycle and have an excessive environmental and landscape impact. Environment and landscape are instead considered important outputs to be integrated as they satisfy the general well-being of the place and its users.

Discussion

The purpose of this brief contribution is certainly not to detail the process in its entirety. Instead, it is to describe an analytical and design model into which it is possible to incorporate knowledge from experimental trials, on which systemic reasoning can be made to support farm choices. The agricultural practice of permaculture is often associated with agroecology. However, unlike the latter, which is recognised and studied as a scientific discipline, permaculture has largely developed separately from academia. However, such methodology is entirely based on scientific knowledge, especially in the areas of ecology and natural patterns. Its founding father considers information to be potentially the most important resource, but it only becomes so when it is acquired and acted upon (Mollison, 1988). Krebs & Bach (2018) consider permaculture to be a design approach for sustainable agriculture, based on scientific assumptions, that is able to create precisely that sustainable management system defined in Regulation (EU) 2018/848, to "*appropriately design and manage biological processes based on ecological systems and using natural resources which are internal to the management system*" with "*the restriction of the use of external inputs*".

Ferguson & Lovell (2014) argue that permaculture's design and practice approach suggests a distinctive perspective and offers promising avenues of inquiry that have not yet been explored by other disciplines, such as perennial polyculture, attention to water management and ecosystemic strategies.

In the light of these considerations, we would like to state that functional analysis as applied in permaculture can be a useful tool when planting and managing an organic orchard, highlighting the strengths and critical elements of the system, and defining goals for further improvement.

References

Abate V. (2015). Impiego di trifglio subterraneo e micheliano per l'inerbimento del frutteto. *Rivista di frutticoltura* **3**: 46-48.

Alessandri S.,Gregori R.,Buscaroli C., Dondini L. (2023). Fingerprinting neccessario per conservare i genotipi della mela 'Rosa Romana. *Rivista di Frutticoltura* **9**: 28-32.

Burgio, G., Magagnoli, S., Bazzocchi, C. (2021). Le infrastrutture ecologiche in agroecologia: analisi delle ricadute sulla biodiversità funzionale, in *Bioreport 2020. L'agricoltura biologica in Italia*. pp. 274-306. Roma, Rete Rurale Nazionale 2014-2020.

Buscaroli C. (2022). Reintroduction of old local scab-resistant/tolerant varieties in organic orchards in Italy. *Proceeding Eco fruit conference* **2022***:* 9-12.

Costa F., Dondini L.,Sansavini S., Alessandri S., Buscaroli C.,Gregori2 R. Rega P. (2020). Centro Ricerca e Inn Rosa Romana patrimonio dell'Appennino da valorizzare sul mercato. *Rivista Frutticoltura* **9**: 43-52.

Dalla Valle, A. Z., Mignani, I., Spinardi, A., Galvano F., Ciappellan, S., (2007) The antioxidant profile of three different peaches cultivars (Prunus persica) and their short-term effect on antioxidant status in human. *Eurofood Res Technol* **225**: 167-172.

Ferguson, R.S., Lovell, S.T. (2014). Permaculture for agroecology: design, movement, practice, and worldview. *A review. Agron. Sustain. Dev*. **34**: 251–274.

Mollison, B. (1988). *PERMACULTURE: A Designers' Manual.* Tasmania, Australia: Tagari Pubblications.

Reiff, J. & Bach S. (2018). Permaculture—Scientific Evidence of Principles for the Agroecological Design of Farming Systems. *Sustainability* **10**:3218. DOI:10.3390/su10093218.