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Chapter 4.2

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CHAPTER

4.2

Permaculture in Commercial Agriculture: Ecology Framework 'One-Eleven' and Four Pertinent Case Studies

Immo Fiebrig[1*], Alfréd Szilágyi[2], Svenja Lohrer[3] and Mai Abbas[3]

[1] University of Nottingham | Notts · National Centre for Macromolecular Hydrodynamics (NCMH)
[2] Hungarian University of Agriculture and Life Sciences
[3] Universität Hohenheim, Societal Transition and Agriculture, Sttutgart, Germany

1. Introduction

In this chapter, we present individual cases of sustainable (regenerative) farming with the intention to inspire and give food for reflection for local action. We consciously avoid a narrative of 'feed the world' imperatives and 'faster expansion' within the concept of an 'ever growing population' (e.g. Fróna et al., 2019). We intend to showcase what systems farmers have developed to lead 'a good life' and to get up every morning, motivated to face the ecological challenges and economic adversities of farming, far away from the business models of corporations linked up to financial markets and their 'commodification' of food (e.g. Rundgren, 2015). This chapter is also driven by the admonition to shun the use of biocidal contaminants from agriculture – and by that – from our food. These comprise synthetic pesticides (and antibiotics), including genetically modified (GM) seeds as part of the intellectual property-protected 'corporate package'. Pesticides are believed by some scientists to create long-term risks to food safety and security and increase the risk of diseases with a long latency period to clinical manifestation. Ailments believed to be caused by pesticides on pandemic scales, such as some cancers or neurologic diseases, must not be a 'collateral damage accepted with approval' (e.g. Dorsey et al., 2020; Leu and Shiva, 2018; Pfrimer and Barbosa Júnior, 2017).

To explore alternative practices, a concept called 'permaculture' (PC) is presented in the context of sustainable agriculture and illustrated by means of a series of four case studies on farming businesses producing food for the market, without the use of synthetic biocides. Farms are seen as examples showcasing the current attempts to regenerate agricultural land and food-producing communities across Europe, based on agroecology as a science and to bring sustainability in a holistic manner to all aspects of the current food system (Wezel et al., 2009; Gliessman, 2015). Farming practices are viewed within the current context of environmental conservation and regeneration, climate change mitigation, and placed within the wider societal perspectives of the UN Sustainable Development Goals (Goals 1-6, 8, 11-13, 15, 16; see UN, 2015).

*Corresponding author: immo.fiebrig@immofiebrig.de

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However, humanity appears to be walking an increasingly fine line – on the one hand, humans are in need of sufficient and nutritious food, while on the other hand. the environment is increasingly being over-exploited to satisfy this very need. Balancing out the requirement to produce and offer healthy nutrition with the need to maintain rich natural ecosystems is one of the greatest challenges of our time. Imbalance manifests itself through numerous problems such as population growth, the limited availability of new agricultural land, the increasing degradation of farmed soil and concomitant loss of biodiversity, decreasing availability of freshwater with increasingly frequent and severe weather events such as lasting droughts and flash floods, and not least the continuous and cumulative contamination with pesticides and fertilizers across the planet (Bünemann et al., 2006; Horrigan et al., 2002). The impact of climate change on agriculture is exacerbating the situation (FAO, 2022). In spite of all efforts, humanity does not seem to get closer to the target laid down in, 2015 with Sustainable Development Goal SDG 2: ending hunger, food insecurity and all forms of malnutrition by 2030 (FAO, 2021). Previous solutions have not attained the necessary ecological balance, while humanity is still seeking alternative solutions to securing food production and equitable access to it, such as so called 'sustainable agricultural practices'. Such solutions can be viewed from a holistic perspective as in UN DESA (2021), along the life cycle of the products and with a special focus on the careful use of all relevant resources, while improving wealth and wellbeing where it has been lacking. Such sustainable solutions in agriculture can be inspired by traditional practices that can potentially "support productive food systems through sound and sustainable soil, land, water, nutrient and pest management and the increased use of organic fertilizers" (UN DESA, 2021).

The integration of PC practices into commercial agriculture – be it as a sideline business or a full-time business – may represent an appealing alternative solution within the science of agroecology due to its alleged holistic design (planning) approach (Fiebrig et al., 2020).

1.1 Agroecology and Permaculture

Agroecology started as a science defining the "ecology between crop plants, soil, soil organisms, insects and insect enemies" (Wezel et al., 2009; Gliessman, 2015**)**. Over time, for example with reference to the 'Declaration of Nyéléni' (2007), agroecology widened its scope, now also representing socio-agricultural movements and sustainable agricultural practices. The literature on agroecology is therefore wide-ranging (Wezel et al., 2009), but it is generally about an ecological approach to agricultural aspects within a human socio-economic context. The Food and Agricultural Organization (FAO) developed 10 principles of agroecology that encompass these aspects: (1) Diversity and Diversification, (2) Co-creation and Sharing of Knowledge, (3) Synergies, (4) Efficiency, (5) Recycling, (6) Resilience, (7) Human and Social Values, (8) Culture and Food Traditions, (9) Responsible Governance, and (10) Circular and Solidarity Economy (10 Elements, n.d.). The association, Agroecology Europe (AEEU), has created a visualization of transition towards agroecology based on the High Level Panel of Experts report No. 14 ("Principles of Agroecology • Agroecology Europe" n.d., HLPE, 2019) showcasing a total of 13 topics, of which seven are related to agroecosystems: (1) Recycling, (2) Input Reduction, (3) Soil Health, (4) Animal Health, (5) Biodiversity, (6) Synergy and (7) Economic Diversification; another six are related to the food system: (8) Co-creation of Knowledge, (9) Social Values and Diets, (10) Fairness, (11) Connectivity, (12) Land and Natural Resource Governance, and (13) Participation.

Scholars entrusted with questions of agroecology often inform themselves away from an institutional perspective, studying instead the realm of traditional practices and bottom-up movements, within different cultures and food traditions. One such grassroots agroecological movement is permaculture (PC), (Ferguson and Lovell, 2014; Morel et al., 2019).

1.1.1 Permaculture: A Grassroots Sustainability Solution

The term 'permaculture' is a neologism made up of 'permanent' and 'agriculture', and was developed by Bill Mollison and David Holmgren in Australia in the 1970s as a creative framework concept for sustainable agriculture and a holistic life in harmony with the environment. By definition, 'sustainability' is already contained in the concept of 'permanent' through the idea of sustaining something continuously over a long period of time.

Mollison and Holmgren had two primary goals: (1) stopping the destruction of the environment by industrialized agriculture and (2) enabling sustainable nutrition for all people. Three ethical principles determined the concept: "care for the earth, care for people, and fair shares".

According to Mollison and Holmgren (1990), the mental approaches following these principles were "efficiency" and "sustainability". This means that input (the human labor to be contributed) and output (yield) should at least balance each other to a highly efficient degree, with a tendency towards a relatively high output. In addition, resources, especially soil, should be managed more than just 'sustainably' in some cases, so that, for example, the humus layer is not only preserved, but lost humus components can also be rebuilt (regenerated).

Mollison and Holmgren (1990) also suggested that applied PC represents a largely self-regulating ecosystem and is thus able to make natural ecosystem services available to humans, while at the same time preserving the underlying functional units (e.g. the microbiota of the soil). This is because a functioning ecosystem provides enough ecosystem services – including food – without losing its resilience.

The fundamental basis of permaculture is thus the sustainable use of natural ecological cycles to create an inexhaustible source of food production not only for oneself but also for the future generations (Mollison and Holmgren 1990), in line with the definition of sustainable agriculture which: "[…] consists of agricultural processes that do not exhaust any irreplaceable resources which are essential to agriculture" (Lehman et al., 1993).

Later, Holmgren (Holmgren, 2004) defined PC as "consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fiber and energy for provision of local needs" and formulated the 12 principles of PC which are now well known within the movement: (1) Observe and Interact, (2) Catch and Store Energy, (3) Obtain a Yield, (4) Apply Self Regulation and Accept Feedback, (5) Use and Value Renewable Resources and Services, (6) Produce No Waste, (7) Design from Patterns to Details, (8) Integrate Rather Than Segregate, (9) Use Small and Slow Solutions, (10) Use and Value Diversity, (11) Use Edges and Value the Marginal,[240] and (12) Creatively Use and Respond to Change.

Applied in practice, the design concept is based on assessing and zoning the entire farm area including the human dwelling. It also includes the cooperative use of plants and animals, i.e. one supporting the thriving of the other synergistically. In planning, one of the most important aspects is the 'functional hedging' of individual building blocks. This means that one function should be covered by several elements, just as each element should fulfill several functions (Mollison and Holmgren, 1990).

The main difference between PC and other alternative agricultural concepts is claimed to be based on its design orientation. In PC, the entire available area is designed into a coherent, resilient (eco-) system during the planning phase, including an assessment of available resources and their qualities ('site planning': Mollison and Holmgren, 1990). Thus, the permacultural approach offers principles that can be mainstreamed to promote the resilience of the agroecological system (Krebs and Bach, 2018).

Today, PC as an international movement for sustainable food production and self-sufficiency experiences limited support from large institutions. However, awareness has been promoted among the general public, for example by private courses and workshops (e.g. the so-called 'PC design

[240] Erratum in Fiebrig et al., 2020: Principle 11 had been omitted.

course'). There are numerous non-science books and documentary film productions (for example, the work of Ben Falk of Regenerative Agriculture – Permaculture Artisans Forum at Permies n.d.; Méndez et al., 2013; Fiebrig et al., 2020; Dörrer, 2021) related to local action, as well as nationally or internationally organized PC associations (for example, the Permaculture Association, 2020 or the International Permaculture Association n.d.) and various demonstration sites across the world, such as Bec Hellouin, France (Ferme Biologique du Bec Hellouin, 2022), Ridgedale Permaculture, Sweden (Ridgedale Farm AB n.d.), or 'LAND centres' organized as a network (Learning And Network Demonstration; Permaculture Association, 2020).

2. Methods

The storyline of this chapter is based on various on-farm exploratory research projects regarded as permaculture practice within commercial settings. The approach had been developed in Germany with actors from primary production, as well as the wholesale and retail industries. The resulting commercial 'permaculture actions' (PA) comprise fields of actions visualized by a graph called 'One-Eleven' (1-11; Fiebrig, 2020) which is based on a wholesaler's guideline (Lehmann natur, 2016). '1-11' stands for 'one prerequisite ' – organic farming certification – and 'eleven fields of actions' that go beyond most current organic certification requirements and are aimed at enhancing the farming system's ecology and its resulting ecosystem services. The specific actions or practices correspond to ecologic themes. Such PC actions may be specified within a 'permaculture re-design plan' according to what is feasible on the farm in relation to human and financial resources and according to what makes ecological sense. Here, the actual conceptualization of 1-11 is supported by fundamental literature research based on the master thesis of Lohrer (2023) with three selected PC farms in Germany and one in the German-speaking part of Italy (South Tyrol). It is presented through the farmers' storytelling and being compared with the 1-11 concept (see also Pražan et al., 2019).

2.1 Storytelling Towards a Deeper Understanding of PC Farming

Case studies presented herein are based on semi-structured interviews carried out with the farm owner where possible, or the farm manager. Care was taken to listen to the story the farmers had to tell about their farm, focusing on its history, the social situation (spouses and other family members, transition to the next generation), and mindset. Details and transcripts are presented in Appendix section 7 (7.1-7.4). It was deemed important to understand the external and internal drivers for change, both monetary and non-monetary. The importance of the storytelling approach is also supported by experience from other authors in enabling and promoting positive change amongst farmers, like the vividness of descriptions from first-hand views and experiences, the sense of identification with the topic, issue or other players, and the mindset of the farmers driving farm processes towards more sustainability (Grace and Kaufman, 2013). One positive effect of being interviewed by a researcher is that farmers may feel encouraged to reflect upon any possible concerns or conversely, feel affirmed and confident in their current farming approach.

3. Commercial Permaculture Framework 'One-Eleven'

European organic farming can be traced back to crises in the late 19th and early 20th centuries, and was influenced by Rudolf Steiner and Demeter (Fiebrig et al., 2020, p. 12). Large-scale operationalization of organic agriculture occurred in the 1950s and 1960s, with certification schemes established in the 1980s and 1990s (Vogt, 2001a and b). Today, organic certification primarily focuses on the absence of synthetic inputs, while restoring environmental integrity is often a stated goal, but is not central to certification auditing. Demeter certification, for example, stands out with additional requirements like 'ecological compensation areas' (Fiebrig et al., 2020; Biodynamic Federation – Demeter International e.V., 2021).

3.1 Eleven 'Permaculture Fields of Actions'

Operationalizing PC on an existing farm producing for the market, especially on a large scale, requires a transition during which it will still have to maintain productivity and profitability whilst allowing some degree of experimentation. The 12 PC principles of Holmgren (2004), considered both deductive and inductive (Krebs and Bach, 2018), may contribute little to operationalizing PC on a commercial farm. The principles give scarce indication as to what design or which processes need to be redesigned and adapted. Thus, internal PC certification requirements were developed by *Lehmann Natur Gmbh* staff in a business case context jointly with internal representatives (of the *r e a l GmbH* supermarket chain) from quality assurance, sustainability, and marketing. Furthermore, an external farm advisor and an independent advisory board comprising three representatives, each from either nature conservation (NGO), consumer protection (NGO), or academia (university) were continuously consulted. Subsequently, Fiebrig developed the graphic representation 1-11 (one prerequisite and eleven fields of actions), based on the type of emblematic visualization of Holmgren's principles (2004) alongside the requirements set by Lehmann (Lehmann Natur GmbH, 2016). The idea was to give a brief answer to the question "What can PC be in commercial settings?" in a way that can be grasped quickly and give guidance to a farmer as to what fields of actions can be addressed depending on context (Fig. 1) without prescribing specific practices (Lehmann Natur GmbH, 2016; Fiebrig et al., 2020).

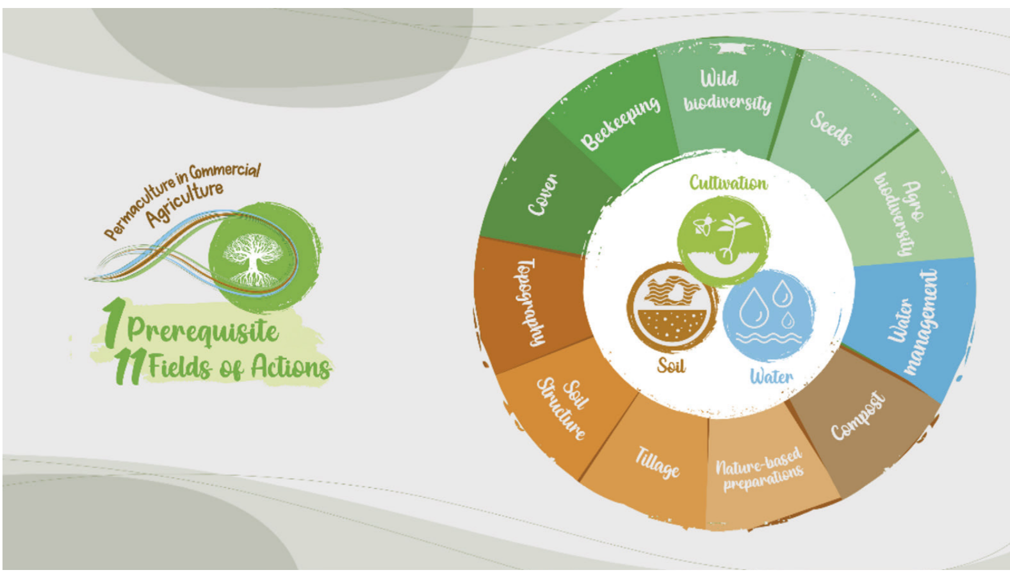

Fig. 1: Graphic representation of PC fields of actions in commercial settings with the one (1) prerequisite (namely organic certification) and eleven (11) fields of actions related to cultivation (greens), soil (browns), and water management (blue). The 11 Permaculture Actions (1) Water management, (2) Compost management, (3) Nature-based preparations/soil amendments, (4) Low and no-tillage systems, (5) Soil structure management, (6) Topography management, (7) Soil cover management, (8) Beekeeping/insect habitat management, (9) Wild biodiversity conservation, (10) Sustainable seed management, and (11) Agrobiodiversity management around the three categories of cultivation, soil, and water management. (Fiebrig, 2020. Graph: Immo N. Fiebrig) ⏎

Farm conversion following the 1-11 concept grants organic certification for consumer protection as a starting point ('one prerequisite') and addresses sustainability on three pillars: water, soil, and cultivation (11 fields of 'permaculture actions'). The image can support the visualization of potential areas for conversion to PC but also convey the interconnectedness of a farming system striving for sustainability and regeneration. In fact, there has been one implementation of the concept so far, which also appeared as a label (r e a l GmbH 2020; Abel 2015); *Lehmann natur* company has been selling the products since 2016 under the 'r e a l Permakultur' label (Figs 2a and 2b) in cooperation with r e a l GmbH (r e a l GmbH, 2020). This may also indicate an increased relevance of 'permaculture' as a topic in the marketing of sustainability concepts.

Fig. 2a: "More nature, more taste, more than 'organic'" was one of the key arguments when launching the 'r e a l.- Permakultur' advertising campaign. ⏎

Fig. 2b: 'Permaculture' was first introduced as a special quality of organic produce being '100% nature"; in-store TV was used to explain the concept of PC and its added value to consumers. ⏎

In addition to its practical orientation, 1-11 has another advantage: the modular principle suggests a step-by-step conversion to ‘full’ PC by implementing only one or more actions within the eleven fields at a time. Even if only one or a few fields of actions are addressed and implemented, an ecologically valuable contribution could still be made.

One-Eleven is nevertheless not detached from Holmgren’s 12 principles. As Krebs and Bach (2018) point out in their review article, each of Holmgren’s principles correspond to at least one agricultural method. However, Fiebrig et al. (2020) have gone a step further with their transcription of the principles into fields of actions, such as designing a (complete) agroecosystem in terms of ecology. In detail, each of the fields of actions includes concrete methods and objectives (Fiebrig, 2020; Lehmann Natur GmbH, 2016), which are briefly elucidated below, starting with water management and moving clockwise on the graph (compare Fig. 1).

Before we turn to the respective significance of the 1-11 on an ecological level, it should be mentioned that specific PC methods have not been invented recently. On the contrary, some very old, traditional practices from traditional agricultural cultures have been combined into a ‘best practices framework’ for sustainability and resilient systems (Krebs and Bach, 2018). Furthermore, Hirschfeld and Van Acker (2021) conclude with their review on ecosystem services in permaculture systems that there is sufficient evidence from peer-reviewed agroecological literature to support the value of (1) crop diversification (2) perennialization, and (3) nature-sparing; all three aspects which are intended to be taken into account in the 1-11 concept.

3.2 Ecological Significance of Fields of Actions

The challenge in evaluating the ecological significance of the eleven fields of actions lies in the fact that we first need to consider them separately, as individual components that may function best, once established, in mutual synergy within their ‘ecology’. On the other hand, many ‘actions’ within the ‘eleven fields’ allow the actions to be implemented gradually and where possible, partially. The 11 fields of actions will be elucidated below with some examples from the literature, as extracted from the master thesis of Lohrer (2023), but without claiming an exhaustive treatise that would go beyond the scope of this chapter. For didactic reasons we start with Fig. 1 from the right hand side of the graph: (1) water management (blue for water), moving to shades of brown (soil related), moving clockwise starting with (2) compost, (3) nature-based preparations, (4) tillage, (5) soil structure, (6) topography, then moving to shades of green (symbolizing relatedness to ‘above soil’), (7) cover, (8) beekeeping/insect habitat management, (9) wild biodiversity, (10) seeds and (11) agrobiodiversity, which will be elucidated by current practices from evidence through science literature. While so-called “gray literature” was not taken into account to illustrate the 1-11 concept throughout, technical reports or non-fiction literature may provide additional valuable practical experience (empirical evidence) with less rigor of a scientific approach, as described for example by Jadrnicek and Jadrnicek (2016).

3.2.1 Water Management

Water management (1) envisages maximizing the infiltration rate and making the greatest possible use of precipitation water through a topographically conditioned water conduit including swales, as well as the collection of excess water in water retention spaces (reservoirs like ponds and lakes). The measures are intended to reduce overall water consumption considerably. The improvement of the infiltration rate through the targeted guidance of rainwater through terracing, keyline design or swales, will be discussed under ‘Topography Management (6)’. Instead, the ecological significance of the second aspect, namely water retention spaces, such as ponds and lakes, will be highlighted here (for the significance of water retention in agroecosystems, see also Ryan et al., 2010).

Fiebrig and Van De Wiel's (2021) investigation of four water retention basins on a PC-inspired commercial orchard in southern Spain (Jelanisol y Montebello) was based on the assumption that water retention has the potential to make ecology on the landscape level, especially in regions with water scarcity, provided retention spaces are of an optimal size in relation to the catchment area and in combination with keyline design and/or terracing.

For the investigation, the authors developed a hydrological model that worked with on-site precipitation data, as well as infiltration and evapotranspiration as free calibration parameters. In the decade before the basins were built, however, there had been above-average rainfall, which is why the size of the water retention basins was designed too large for the actual average rainfall. Besides, average evaporation is at least three times as high as average precipitation. The water harvesting potential is therefore limited here. Fiebrig and Van de Wiel (2021) thus concluded that water retention spaces should be adequately planned in accordance with catchment size, precipitation and evaporation parameters, as well as being investigated long-term to confirm their additional contribution in reversing desertification processes in the Mediterranean and mitigating climate change. At the same time, the water retention reservoirs (ponds and lakes) serve as (semi-) natural habitats in the sense of action fields (8), (9), and (11) – the authors were able to observe amphibians in the vicinity of the basin. It can be assumed, and remains to be investigated, whether other wildlife such as bees and birds adopt the localities, as habitats had been noted on another PC-inspired land restoration project in Spain, where a series of interconnected ponds and lakes had been created (Fiebrig et al., 2020; "Una Dehesa Sostenible" n.d.). It is important to note that such water reservoirs may act as traps for fauna if used for irrigation or if regular drying out is to be expected.

3.2.2 Compost

Compost (2) and its management serves the continuous water and nutrient supply to plants, strongly simplified by means of increasing the humus content and thus the content of soil organic matter (SOM) to soil-dependent and climate-dependent optimum values. For this purpose, compost and other organic fertilizers are to be used, which, if possible, originate from the farm's own production or at least from regional sources (circular economy). The alternative of compost as a part of soil amendment based on the animal or plant 'waste' offers, on the one hand, the possibility of disposing of this waste by simply allowing it to flow back into the ecological cycle. On the other hand, the application of organic fertilizer in the form of animal manure, in particular, leads to a significant increase, or at least maintains the original content, with regard to the organic carbon SOM present in the upper soil layer (~25 cm) as indicated by the results of a long-term field experiment published by Raupp and Oltmanns (2006). After nine years, the highest levels of SOM were found in the upper soil layer of the plot treated with the most compost, including animal manure and biodynamic preparations.

Fließbach and Mäder (2000) used another indicator to investigate the effect of different fertilizers, including compost, on the soil, but reached similar results. They measured microbial biomass and size-density fractions in soils in an (ongoing) long-term experiment comparing biodynamic, organic, and conventional forms of agriculture (within the so-called "DOK experiment": biodynamic, organic, conventional [FiBL – *DOK-Versuch*, n.d.]). The experiment had already been running for 18 years. The specific study showed that the microbial biomass in terms of C and N as well as the quotients of $C_{microbial}$ to SOC and $N_{microbial}$ to N_{total} were higher in the organic systems than in the conventional ones. This indicated an increased decomposition activity due to higher microbial biomass in the biological systems. However, the levels of SOC were hardly influenced by the measures.

A more recently published analysis related to the "DOK experiment" evaluated fertilization for making agricultural soil a more effective carbon store after 36 years (Mayer et al., 2022).

A conventionally and a conventionally-organically fertilized field were both compared with a biodynamically fertilized field, i.e. with composted manure, versus an unfertilized control field. Although no additional storage of mineral-associated carbon in the clay fraction under any of the fertilization forms could be measured, the total amount of SOC was increased by 13% under fertilization with composted manure, versus only 5% SOC in the conventional-organic trial field. In both the control and the mineral fertilizer trial, the total amount of SOC decreased sharply. In addition, the qualitative differences of the fertilizer, together with the absence of pesticides in the biodynamic trial field, apparently ensured a significantly higher carbon content. Particle-bound SOC is assumed to correlate with the amount of aggregates (Mayer et al., 2022).

Tung and Fernandez (2007) also compared four farming systems: (1) the organic system was based on cow manure and plant-based pest control; (2) the 'biodynamic' system on biodynamic preparations only, no fertilizer and no pesticide; (3) the chemical system was run on synthetic fertilizers and synthetic pesticides, and (4) the control group received no fertilizer, no pesticide. In summary, the organic system performed best, with the largest increase in SOM, the largest earthworm population, the highest yield, and the highest net yield.

Szilágyi et al. (2021) also conducted a comparative study that included PC farming systems. The authors investigated the differences between conventional, organic, and PC vegetable farmers in Hungary with regard to earthworm populations in the soil, as earthworms are considered an important indicator of the condition of the soil. At least in May, earthworms were higher in both abundance and species richness, on PC farms. In contrast, earthworm abundance on the conventional and organic farms was not increased at any time compared to the PC farms (Szilágyi et al., 2021).

Finally, it remains to be seen that the application of animal compost manure, depending on soil quality and additional agricultural practices, contributes at least to a maintenance, if not an increase, of soil carbon. This subsequently influences microbial soil activity positively and ensures increased availability of plant nutrients. In addition, carbon sequestration has a positive effect on the climate. Thus, an overall positive effect tends to be obtained without the detrimental consequences of synthetic fertilizers. Mulching, which is much described in the context of PC practice, is dealt with below under the section 3.2.7 'Cover'.

3.2.3 Nature-Based Preparations

'Nature-based preparations' (nbP) as soil amendments (3) refer to a group of treatments with compost teas, microorganisms, herbal extracts, essential oils, homeopathy, beneficial organisms, etc., but clearly excludes synthetic/mineral fertilizers.

There is considerable disagreement in the literature about the effectiveness of the biodynamic preparations applied in accordance with Demeter standards. For this reason, a clear distinction is made between other nature-based preparations in the sense of the 1-11 concept according to Fiebrig (2020) and the eight defined preparations according to the Demeter guideline (Biodynamic Federation – Demeter International e.V., 2021), without making a value judgment herewith.

The biodynamic preparations according to Demeter are clearly defined in their production and composition (Chalker-Scott, 2013) and are obligatory in certified Demeter agriculture; no such definition is made for the nbPs to be used. However, farmers dedicated to sustainable or regenerative forms of agriculture (agroecology) are experimenting with such preparations.

Considering the keywords 'beneficial organisms', we can look back on a long history of Integrated Pest Management (IPM), in which humans have made use of the natural feeding behavior in nature for biological pest control in agriculture (van den Bosch et al., 1982).

Recent findings exemplify the excellent efficacy of *Trichogramma* species against lettuce pests. In fields with lettuce, which grows worldwide and is frequently affected by *Fusarium* wilt (caused by *Fusarium* fungi), the rhizosphere was enriched with various mixtures of *Trichogramma* species. After two years, a decrease in *Fusarium* wilt of 50 to 70% was observed. There were no negative effects on the soil microbiota (Bellini et al., 2023).

A similar effect on *Fusarium* inhibition was achieved by the application of compost tea (Ou-Zine et al., 2022). Ou-Zine et al. had investigated the different modes of action of compost teas at two different concentrations, with or without enrichment with organic additives such as humic acid, molasses, and date syrup, and after 24 h or 48 h brewing time in each case. The enriched compost teas generally showed an increased value of organic and important plant nutrients. *In vitro*, all compost teas showed an inhibitory effect on *Fusarium*, but the highest with an inhibition rate (IR) of more than 83% was shown by the 48 h brewed 'enriched' compost teas.

Application of the enriched compost teas under greenhouse conditions to maize showed increased plant growth and increased populations of rhizosphere bacteria, although root colonization with AMF (arbuscular mycorrhizal fungi) was not affected. Consequently, the authors suggest that enriched compost teas should be considered as a sustainable alternative to synthetic fertilizers. Generally, it is accepted that microbes in the soil provide numerous benefits to plants, including growth stimulation, nitrogen fixation, protection from root diseases, and improved water retention. In their review, PC and regenerative agriculture systems enable biotic and abiotic influences that can have a positive impact on the production of important secondary metabolites in medicinal plants (Courie et al., 2024).

According to recommendations by Lehmann Natur GmbH (2016), these preparations can be used if deemed necessary. We believe that more and long-term research is needed to establish the effectiveness of the different treatments.

3.2.4 Tillage

Fields of actions around 'tillage' (reduced tillage systems) comprise the reduction or complete abandonment of tillage to reduce soil disturbance and concomitant erosion, as well as fuel consumption; it can include ridge crops or mound beds. Cultivation in ridges can be additionally helpful in saving water. Low- and no-tillage systems (conservation tillage) belong to the idea of 'conservation agriculture' and are a common topic of research in sustainable agriculture approaches to protect the soil biota, whilst improving soil fertility and preventing erosion (Cannell et al., 1986; Carter, 1994; Pekrun et al., 2003). Whereas in PC systems, arable farming is not typical (Fillippi, 2013), sustainable arable approaches have been developed based on the Turiel ridge farming system (Müller, 2010; see Kiliani Farm, section 4.2 below).

In organic agriculture, an improvement in soil fertility was demonstrated, for example, by Berner et al. (2008) in a three-year study as part of the 'DOK experiment' mentioned earlier (FiBL – *DOK-Versuch*, n.d.). The influence of tillage, fertilization (conventional vs. organic/biodynamic), and biodynamic preparations on five indicators of soil fertility: (1) SOC, (2) microbial biomass C_{mic}, (3) dehydrogenase activity DHA, (4) earthworm density, and (5) their biomass and the influence on crop yield were investigated.

As a result, reduced tillage had an impact on these indicators, with SOC in the upper soil layer (0-10 cm) increasing by 7.4%, C_{mic} by 28%, and DHA by 27%.

Considering the earthworm population, there was no meaningful result; although the occurrence of earthworms was 70% higher in the low-tillage system, their biomass was however more than halved as opposed to the conventional tillage system.

The crop yields of wheat (*Triticum aestivum* L.) and spelt (*Triticum spelta* L.) were somewhat reduced in connection with the low-tillage system (between 8 and 14%), whereas the sunflower yield (*Helianthus annuus* L.) increased slightly (Berner et al., 2008).

After 15 years, the same experiment was also evaluated with regard to the influence of the two tillage methods on soil quality. A cumulative increase of SOC by 25%, of C_{mic} by 32%, and a 34% increase in DHA on the low-tillage compared to the conventional tillage plots was recorded (Krauss et al., 2020).

In organic agriculture, it can be said that soil fertility could be increased by the low-tillage measure, with minor crop losses of the crops studied here. Other review papers conclude less favorably about conservation tillage. In temperate regions especially, N availability in spring is lower and weed pressure is higher, sometimes resulting in lower yields (Cooper et al., 2016; Zikeli and Gruber, 2017; Peigné et al., 2018) and a rather inconsistent picture with only very little SOC enrichment (Krauss et al., 2022).

3.2.5 Soil Structure

'Soil structure' and its management means that, for example, the soil structure should be monitored on critical sites on a farm over time in order to loosen any compaction through mechanical measures and/or green manuring, in addition to the reduction of soil pressure on the track by the use of light machinery and broad tires to avoid compaction. According to Özbolat et al. (2023), a sustainable form of soil structure management comprises a combination of reduced tillage and green manuring, especially under sensitive soil conditions. This claim is based on a 10-year study of Mediterranean rain-fed almond orchards. The effects of conventional tillage (CT), reduced tillage (RT) and reduced tillage in combination with green manure (RTD) were compared. The green manure here consisted of oats (*Avena sativa*) and forage vetch (*Vicia sativa*), which were planted between the almond trees in the form of alley cropping.

Significant was the increase in total carbon, particulate carbon and total nitrogen content in the soil under RTD. Similarly, under RTD there was an increase in macroaggregates and the relative abundance of *Solirubrobacteraceae*, *Streptomyces*, and *Solirubrobacter* in the soil. None of the three management practices had significant effects on almond yields.

Pelosi et al. (2009) investigated the effects of a living mulch cropping system with no till compared to organic and conventional arable cropping systems – varying crop rotations with oilseed rape, peas, wheat, maize, and lucerne – on the earthworm community in the respective soils. It was found that the functional composition of earthworms can be influenced or changed by the cropping method. The density and biomass of anecic and epigeic earthworms were higher (64%) in the living mulch system than in both other systems. In the conventional and organic systems, the proportion of epigeic worms was 75%. In addition, the living mulch system performed comparatively better in the Schannon-Wiener and equitability indexes. Accordingly, the cultivation system, in this case green manuring in combination with no till, influences the functional composition of the earthworm populations and thus causally, the physico-chemical soil properties. The high diversity indexes ultimately contribute to greater resilience of the system.

3.2.6 Topography

'Topography' and its management relate to water management (section 3.2.1). It takes into account slope and intends to mitigate soil erosion by precipitation whilst improving water infiltration. Crops could be cultivated along contour lines; in specific cases, terracing may be an option, where appropriate. Indeed, steep slopes are often overcome by cultivation on terraces, yet building and maintaining terracing is costly and many examples are related to traditional or historical peasant farming mostly in high mountain areas. More common in the PC discourse is 'keyline design'. The term goes back to its inventor and developer, the Australian farmer and engineer P. A. Yeoman. This special type of terracing, starting from a so-called 'key point', is supposed to have a positive influence on soil fertility, water balance, and agrobiodiversity (Hill, 2003). Studies specifically on Yeoman's keyline design are hard to find, but many researchers have already studied the ecological effects of terrace farming and this may allow some conclusions as to keyline design as well. Terraces were already in use to cultivate crops in Southeast Asia 5000 years ago (Price and Nixon, 2005).

In the review article by Deng et al. (2021), the advantages and disadvantages of terrace farming of various types is discussed, without specifying slopes, and comparing studies from all continents to show that terraces protect plant biodiversity at the local level, increase grain yield and soil water content, and reduce surface runoff, which in turn curbs soil erosion.

On average, terracing reduced surface runoff by more than 41.9% and sediment erosion by 52% compared to natural slopes. Grain yield on terraces was higher by an average of 44.8%, and soil water content by 12.9% (Deng et al., 2021).

However, not all terraces are the same. In a comparative study of grassed and non-grassed terraces cultivated with maize, Fernandes and Gontijo (2020) concluded that grassed terrace slopes not only contain soil erosion better than non-grassed slopes, but also offer the possibility of deflecting plant pests. Instead of maize, plants that were eaten by general pests grew on the grassed slopes. In addition, the grasses growing spontaneously on the slopes provided a habitat for natural predators of these pests, which further increased plant protection. In effect, the amount of damaged maize plants during the two-year study was twice as high on the ungreened slopes as opposed to the greened ones.

Negative impacts of terraces are "usually due to inadequate planning, mismanagement and abandonment of farming" (Deng et al., 2021). Thus, as Fernandes and Gontijo have shown, terrace farming depends on 'proper' management (Fernandes and Gontijo, 2020). Negative consequences of terrace farming can include interruption of water circulation, erosion due to poorly designed terraces, deterioration of soil quality, and soil erosion after abandonment of terraces. However, there is a lack of comparative studies here, as there are many different terrace forms and terrace materials whose function or effect depends not only on these factors, but also on geographical location and planting (Deng et al., 2021). Consequently, studies are needed for each type of terrace in each possible geographical location in order to clearly predict an ecologically valuable contribution through terracing. On the other hand, mechanization of terraces remains a challenge and cultivation is often abandoned due to the amount of labor required. Keyline cultivation may be an alternative, at least for moderate slopes, still allowing mechanized farming. To establish a cost-benefit analysis in keyline farming, long term and complex studies are needed that substantiate the benefits over their cost.

'Swales', as often recommended in PC to direct water flow and promote soil water storage, were not considered in this review for lack of practical relevance in the farm examples presented below and also due to lack of relevant peer-reviewed scientific literature.

3.2.7 Cover

'Cover', i.e. 'soil cover management' refers to the year-round maintenance of soil cover. This can be achieved by planting locally adapted varieties of cover crops and/or allowing the growth of wild herbs, and by mulching with natural materials, for example plant waste, provided such mulching is not contraindicated due to potential habitat creation for pest populations.

Since plastics are generally not to be used for mulching in soil cover management under the 1-11 concept, a comparison of the effect of organic and inorganic mulches seems useful, as presented by Agarwal et al. (2022) in a recent study. In an important tomato-growing area in Uttarakhand in the central Himalayas, the authors studied yield density, cropping duration and weed incidence under different mulching materials during one growing season (2017-2018). It is true that mulching with polyethylene produced higher results in terms of yield compared to organic materials (rice straw, kans grass and dencha husks). Nevertheless, the study showed that mulching, even with organic material, generally increases crop yield. Among the organic materials used, the treatment with rice straw was the most successful. Likewise, all mulch variants were able to reduce weed density. However, the harvest duration (day of the first harvest to the day of the last harvest) was only very slightly increased by organic mulch materials compared to the control group (Agarwal et al., 2022).

A particular study published by Ciaccia et al. (2016) used ‘living mulch’ (LM) for weed management in organic vegetable cultivation. One study site was located in Denmark where *Allium porrum* L. (leek) was intercropped with *Isatis tinctoria* L. (dyer’s woad) LM strips. In Italy, in turn, intercropping was performed for *Brassica oleracea* L., var. *botrytis* (cauliflower) with *Medicago polimorpha* L., var. *angolana* (burr medic) at early and late sowing and compared with a no-LM control. Weed management could be achieved and smothering of the crop by weeds was avoided. The later sowing worked better.

Generally, mulching may have an effect on increasing slug populations and subsequent slug damage, which in turn may require adequate pest management (for example Kennedy et al., 2013).

3.2.8 Beekeeping

‘Beekeeping’ describes the keeping of honey bees (*Apis mellifera*) and the promotion of wild bee species by creating natural habitats such as flower strips, where appropriate, through collaboration with local beekeepers.

Pollination by bees – honey bees as well as wild bees – brings significant advantages in terms of fruit quality and consequently, in terms of the commercial value of the crop. This was shown by Klatt et al. (2014) on nine economically important varieties of the strawberry species, *Fragaria x ananassa DUCH*. In their study, it was shown that insect pollination produced larger, heavier and firmer fruits than self-pollination and wind-pollination, and also produced a higher number of fruits. In addition, those strawberries from bee-pollinated plants had a fuller color and lower sugar-acid ratio. All these characteristics lead to a much higher market value. The better quality of the fruit is probably due to hormonal processes triggered by bee pollination (Roussos et al., 2009) and occurs not only in strawberries but also in numerous other pollination-dependent plants (Toivonen and Brummell, 2008).

Now, human-pollinated plants could also achieve the same or even better results in fruit quality. This is at least suggested by the example of apple orchards in Maoxian County, China (Gowdy et al., 2013). There, years of frequent pesticide use and exploitative honey harvesting nearly wiped out pollinator insects, leading to the initially necessary evil of hand pollination. However, it soon became apparent that pollination by humans brought advantages from an economic point of view - among others, that the flowers were all pollinated, and very correctly and cheaply at that. There was no need to reduce the use of pesticides as the pollinating insects were no longer needed.

However, when looked at more closely, this example only shows that a monetary valuation of ecosystem services alone is not sufficient to determine the actual value of this service. A consideration from several perspectives is necessary. With regard to the example of Maoxian County, in addition to the monetary perspective, the aspect of sustainability questions the large-scale and high-dosage use of pesticides.

In the strawberry trial by Klatt et al. (2014), wild bees (mainly *Osmia bicornis* L.) were more abundant than honey bees (*Apis mellifera* L.), probably due to low temperatures. This fact leads to the question of whether the ‘beekeeping’ should focus on the keeping of honey bees only or be extended to general ‘insect habitat creation and management’. Notably, honey beekeeping makes a directly marketable product possible.

Taking the results of Rogers et al. (2014) a step further, it is rather a matter of achieving the greatest possible biodiversity among bees, which consequently includes the promotion of mainly wild bees. The researchers investigated the relationship between pollination performance and bee species abundance on cultivated blueberry plantations.

The authors of the study concluded that for stable and efficient pollination performance, a high richness of bee species was more important than abundance of individual species. This is probably mainly due to the diverse responses of different species – different species react differently to environmental fluctuations such as the weather. Therefore, a wide range of species also compensates for a wide range of environmental conditions, thus increasing pollination success (Rogers et al., 2014).

3.2.9 Wild Biodiversity

'Wild biodiversity' means promoting natural biodiversity through natural habitat conservation or creation such as hedge elements, re-structuring the landscape, or near-natural forest edges, including the creation of corridors and connection to the landscape. Specifically, allowing for local insect-friendly plants and water points or ponds (see also section 3.2.1, 'water management') can be considered synergistic for wild biodiversity promotion.

Biodiversity is the basis of many ecosystem services, as these are based on functioning, resilient ecosystems (Reid et al., 2005). The protection of biodiversity is therefore crucial for the preservation of important livelihoods. Thus, the conservation or restoration of biodiversity in sustainable agriculture must be both a prerequisite and a goal.

Natural and semi-natural habitats in direct and indirect proximity to agricultural land have been identified as an important factor in achieving this goal (Carvalheiro et al., 2010; Dainese et al., 2015; Outhwaite et al., 2022).

Dainese et al. (2015) investigated whether (semi-)natural structures at the field edge (grass, or simple to increasingly complex hedgerows) or the availability of semi-natural habitats in the vicinity of 0.5 and 10 km have different effects on biodiversity. The authors investigated the effects on species richness of the three taxonomic groups of vascular plants (*Tracheophyta*), butterflies (*Lepidoptera*) and caterpillar flies (*Tachinidae*) in a Mediterranean region of north-eastern Italy.

In particular, among vascular plants, a greater richness of species was observed in extensive grass margins, while hedgerows supported butterfly and caterpillar biodiversity. In addition, species richness among butterflies was dependent on wooded areas within 0.5 km of agricultural land. Butterflies were also the only group that was still positively influenced by semi-natural habitats at a distance of 10 km (Dainese et al., 2015).

In addition, it was shown that, especially for wild bees, there was a negative correlation between increasing distance of natural habitats from the pollination site and number and richness of species. Pollinating ants, on the other hand, were not affected by the distance. This was concluded by Carvalheiro et al. (2010) from their studies on mango plantations, where both ants and wild bees were found to be the two most effective pollinator groups. The study was conducted on mango farms in South Africa, the farms located between two large conservation areas. Both conventionally and organically managed farms were included, with and without their own honey bees. In addition, only one mango variety (Kent) was under observation.

Neither the presence of managed honey bees nor the application of pesticides had a significant impact on the pollinator community. Natural habitats within a 0.5 km radius of the mango plantation, however, significantly influenced the abundance and species richness of wild bees. In addition, food web analyses conducted within the study concluded that a diverse food web (in this case, flowers) on the farmland can contribute to the maintenance of pollinator communities (Carvalheiro et al., 2010).

In the pursuit of broad biodiversity, attention should therefore be paid to an equally broad selection of habitats, including food resources, and their installation within a radius as large as possible. However, promoting wild biodiversity may also invite predators, thus posing a risk to crops and young trees (e.g. meadow voles, wild boar, and deer), animal husbandry (e.g. fox) or to operators (e.g. poisonous snakes in tropical and sub-tropical climates) and tourists (e.g. bears). These may require adequate management to maintain agroecological balance.

3.2.10 Agrobiodiversity

'Agrobiodiversity' management is – at the level of origin and effect in the agricultural context – so strongly linked to general biodiversity that one could also treat both as one field of action. According to the Food and Agriculture Organization of the United Nations (FAO) 1999, agrobiodiversity is defined as the totality of "genetic resources for food and agriculture" that has been developed over centuries. These genetic resources include, on the one hand, crop plants, domesticated animal breeds, and wild animals that can be hunted. On an indirect level, however, they also include the resources that support food production, such as the soil microbiota, wild pollinators, and many other insects and other beneficial organisms like birds and small mammals.

Just as already described above under 'Wild Biodiversity' (section 3.2.9), food production as an ecosystem service is based on the complex interaction of biodiversity elements in the long term.

At least the diversity of domesticated plants and animals can be directly controlled, unlike wild organisms, whose development and conservation can only be supported. This detail is ultimately the reason for the separation of the two topics, which is why the focus will now be on precisely this area of agrobiodiversity in the narrowest sense.

An important keyword in the field of agrobiodiversity is agroforestry, since a high degree of (agro)biodiversity is imminent here simply because of the integrated cultivation of perennial trees, shrubs, palms, etc. with agricultural crops in partly multi-story systems. A survey of agrobiodiversity at three traditional oases in Tunisia (Santoro et al., 2020) should serve as a first example here, albeit not in Europe. In this survey, 25 different date palm varieties and 21 fruit tree species were counted, and here, in contrast to modern Tunisian oases, there were more than 150 palms per ha planted in a disorderly manner (in modern oases, there are 100-150 palms/ha planted in rows). In addition, 21 vegetable varieties and two fodder plants were cultivated in the three oases, as well as some medicinal plants or herbs such as *Ricinus communis* and *Mentha spicata*. The different groups of crops were grown in a three-tier system. The traditional oases were managed manually, with the cultivation of different species in mixed systems, i.e. polycultural. Animal husbandry was part of all three oases, as animals are raised for field work and their dung is used as fertilizer. Animal species included camels, sheep, and various breeds of goats. The authors of the study concluded from their survey that the three oases were a good example of high agrobiodiversity at the landscape level.

Another example that makes successful use of agroforestry is traditional coffee cultivation, which is widespread in the mountain regions of Cuba. Although here the commercial side is in the foreground, the interaction of the different plants in the agroforestry systems enables local farmers to produce additional food for themselves, as well as for sale. In addition, the trees shading the coffee provide a more favorable microclimate for them to thrive, but also for the microbiota of the soil as well as for wild and other cultivated plants. Consequently, this example also supports the link between traditional agroforestry and the preservation of a large agrobiodiversity (Agnoletti et al., 2022), which is apparently also applicable to products such as coffee that are mostly produced by intensive agriculture. The authors chose to study two very important coffee plantations in Cuba that were equally operated as traditional agroforestry systems, both located in mountainous regions, and serving as examples of the sustainability and climate relevance of such systems.

These 'traditional polyculture coffee gardens' basically consist of the original forest, with only the lower shrub layer replaced by coffee plants (*Coffea*) and other crops. Such a system achieves comparatively low yields, but is very labor-extensive to manage and produces a maximum of 'useful biodiversity'. The wealth of plant species here includes up to 120 different trees, shrubs, and herbs. In some cases, farm animals are also kept in the coffee gardens, apart from the up to ~600 species of arthropods that have been counted in a coffee garden in Mexico from the soil layer up to a height of 2 m (Moguel and Toledo, 1999).

This high agrobiodiversity is based on the interactions and nutrient cycles within the system; nutrients enter the system through various entry points such as precipitation or foliage. There are also interactions between the vertical levels. For example, mineralization processes in the soil are favored by the shade trees and the litter, as these result in slower evaporation. The litter causes an increase in the occurrence of decomposers, while beneficial organisms are favored elsewhere. In addition, soil organic carbon content is maintained by the interaction of litter and shade (Agnoletti et al., 2022). Agroforestry in tropical and subtropical climates potentially offers a richness of plant species stacked in a relatively small area. In Europe, with colder climates and fewer hours of sunshine, there are many examples of traditional agroforestry and agrosilvopastoral systems. These include the *dehesas* in Spain, the *montado* in Portugal, or the wooded pastures and meadow orchards (*Steuobstwiesen*), for example in Germany or Switzerland, as extensively managed landscapes (Rigueiro-Rodríguez et al., 2010, also see section 5.3, Farm Stöckl). Such systems might offer great potential for the future conservation and development of agrobiodiversity, be it for regional heirloom varieties or for the development of varieties being adapted to expected or current regional climate changes. PC projects – by definition, biodiverse 'forest gardens' – can also be found. Usually, they tend to be much smaller than commercially run agroforestry systems, and may serve well as demonstration sites, more than for their productivity towards marketable fruits or nuts. Practically oriented literature on forest gardening is extensive and, we believe, PC 'food forests' as hubs for agrobiodiversity must not be underestimated and should receive more long-term support (for example Jacke and Toensmeier, 2008).

3.2.11 Seeds

'Seeds' and their management refers to the use of organically produced seed and planting material. The focus should lie on traditional, heirloom, resistant, tasty, and locally adapted varieties, the latter including adaptation to climate change. Wild varieties should also be considered, possibly with seeds from one's own propagation, and non-chemical seed treatment is expected.

In the face of environmental degradation caused by industrial agriculture, climate change, and a growing world population with a consequent increase in food demand, there is a growing awareness of the potential benefits of traditional varieties compared to high-yielding varieties (HYV), e.g. traditional rice varieties (Krishnankutty et al., 2021; Thrupp, 2000; Zhu et al., 2003). Traditional crop varieties have been in steady decline since the Green Revolution, when they were replaced worldwide by hybrid varieties. At that time, these HYVs were bred to ensure food security, as the new varieties achieved far higher crop yields. However, their cultivation also required the use of chemical fertilizers and pesticides, insecticides, and mechanized methods (Cleaver, 1972).

Today, traditional varieties are viewed differently by scientists. They have great potential to contribute to sustainable agriculture (Krishnankutty et al., 2021) because such varieties, through their genetic variability and local adaptation, are much better able to cope with fluctuating environmental conditions without requiring the (excessive) use of chemical substances (Huang et al., 2016). The supposed benefits of HYV not only cost more in the long run – destruction of biodiversity and consequent collapse of ecosystems and corresponding ecosystem services – but even in the short run, according to a study of rice fields in Assam, India (Gogoi et al., 2020), the cost of growing HYV is almost 30% higher than growing traditional varieties, due to chemical pest management, irrigation, and the purchase price of seeds.

Due to their genetic diversity, traditional plant varieties (and also animal breeds) play a major role in future food security and the preservation of (agro)biodiversity, not least also for the adaptation of food production to climatic changes (Jacob et al., 2021).

3.3 Concluding Remarks on PAs

From an implementation point of view, the described fields of actions and the 1-11 concept seemed practical enough to motivate (organic-certified) farmers interested in PC to make alterations on their farm towards more ecologically sound operations, thus qualifying for internal review by *Lehmann natur*. Discussions with members of the advisory board indicated that the Lehman et al. (1993) definition of sustainable agriculture could be largely met, especially if ongoing farm conversion and ecological improvements are considered, planned, and executed in the long run. How much 'permaculture' a commercially operated farming system needed and permitted, considering implementation costs and workforce requirements, remains a topic of debate, which is not surprising considering the pioneering efforts of farmers, the wholesaler, and the retailers. Whether or not the application of 1-11 ecological fields of actions, in partial or complete farm conversion, can also ensure competitiveness under social and economic equity also remains to be examined in future.

There are conflicting opinions over the inclusion of animals in PC farming systems (see section 3.2.2 'Compost' and the inclusion of manure) whilst remaining in line with the original idea of PC by Mollison and Holmgren (1990). With regard to animal husbandry, traditional, rare landraces are preferred to support livestock biodiversity.

Finally, we want to take 1-11 a step further from theory into practice and look below at four case studies where PC-related ecologic actions have been implemented.

4. Applied PC and Farming Descriptions

This part of the chapter will showcase a total of four farming projects across Germany (three) and South Tyrol, Italy (one), based on the farmers' storytelling, to show at least some of the actions from the eleven fields (see also Pražan et al., 2019). PC actions should be implemented in the production system in some impactful way and go beyond the bare minimum set out by organic certification schemes. The farming system may be explicitly based on ʿpermacultureʼ design principles and PC practice, or on ʿagroecologyʼ as the underlying science and practice within Europe. Farms were selected arbitrarily via recommendations ('word of mouth') within networking activities and depending on the willingness of the farmer to show their farm and give an interview between spring and summer of 2022. Two of the four farms had already been suppliers of 'permaculture produce' to *Lehmann natur* (Stöckl's farm and Kiliani Farm), followed by Farm Luna which keeps a strong link to the German Permaculture Association and hosts its own PC teaching courses; Salmsein Farm had been a recommendation from Stöckl's farm due to its long generational history ("traditional") and the inclusion of animals in a challenging alpine climate and a region with intense tourism. Care was taken to present the farms in a structured and uniform manner where possible. Kiliani Farm, as opposed to the others, had already been described in a technical agricultural journal and the local newspaper, which allowed us to make reference to or cite from these sources.

Where possible, comments taken from farmer interviews using a semi-structured questionnaire may be included to underpin the ecologic, economic, and societal benefit, such as to serve as a project of reference (see appendix for verbatim from the interviews). Gaps between current policies and the implementation of best practices will be pivotal to the resulting conclusions. Farms are presented through a brief description, and a structured farm profile with additional facts and figures from the farmer's personal story in relation to PC based on three questions: (1) What guided the change towards PC and when? (2) What kind of PC-related plan/design was developed and how? (3) What are the most salient aspects of PC you implemented on your farming system, for example ecologically and socio-economically? The response to the third question is then presented as a listing of salient PAs, i.e. those that are considered most important within the framework of 1-11 and PC.

4.1 Farm Luna, Freden, Germany: Rare Animal Breeds

Farm Luna is an owner-managed mixed production system that has been farming biodynamically since 1987. Since that time, the main focus has been the integration of animal husbandry, landscape design and nature conservation to build a stable overall ecosystem.

A closed operating cycle produces fodder for the animals, whose manure is subsequently spread back onto the fields with added wood chips from hedge coppicing; this, together with a varied crop rotation, is assumed to aid the continuous build-up of humus.

Three rare and endangered livestock breeds – the old breed of *Angler* cattle, the *Bunte Bentheimer* pig, and the Hungarian *Racka* sheep – are kept and bred. This entitles the farm to denominate itself as '*Archehof*'[241] by the GEH (*Gesellschaft zur Erhaltung alter und gefährdeter Haustierrassen* = Society for the Conservation of Old and Endangered Livestock Breeds) as a breeding and presentation site (GEH n. d.).

Largely heirloom varieties of grain are being cultivated from own seed production. Furthermore, on areas of marginal yields of the *Wernershöhe*, about 15 km from the farm house, management is geared to allow the growth of rare farmland wild herbs alongside grain as part of a contractual nature conservation program of Lower Saxony (*'Vertragsnaturschutz' Land Niedersachsen*). This entails promoting the extensification of cultivation methods on arable land though direct payments, in order to preserve endangered and highly endangered plant species and communities. As part of a five-year commitment, multi-annual conservation areas are to be established and managed according to specified management, e.g. *refraining from harvesting* the grain produced (AUKM n.d.).

A varied farmland design with hedges, meadows, avenues of fruit trees, flower strips, fields, and wetland habitats creates penetration zones for a rich variety of species and a high level of biodiversity (see Fig. 3).

Fig. 3: Main farmland pertaining to Farm Luna with arable land and orchards (foreground); arable land, grassland, hedgerows, and farm buildings including animal husbandry (dairy cows; background). (Photo: Immo N. Fiebrig, 1 March 2023) ⏎

Farm Luna is additionally hosting the Learning Place Living Agriculture that offers courses on PC in collaboration with the German Permaculture Association, including a seminar room for teaching and open-air socializing spaces as well as a participatory kitchen ("Lebendige Landwirtschaft auf Hof Luna." n.d.).

4.1.1 Farm Profile

Operation: The farmland (see Table 1) is cultivated using biodynamic cultivation methods according to the following breakdown: 40 ha of **arable land**, 25 ha **agricultural 'wild herbs'**

[241] Ark farm: it farms endangered animal breeds.

Table 1: Basic farm profile of Farm Luna ⏎

Farm name	Geographical location	Area, ha	Soil type	Climatic conditions		
				AAT (°C)	AAP (mm)	AMSL (m)
Luna	Germany (North)	170	20-60 BP[242] German Index; clay soils, weathered lime soils, loamy soils	8.8	500-650	100-330

Full-time sole proprietor business; staffing: varying full-time staff and volunteer work.

Marketing: direct on-farm from shop: frozen meat, canned meat, fresh fruits, cereals, potatoes.

Main income: Dairy to *Bioland*[243] milk collection by organic farming association.

protection area (see Fig. 4), 84 ha of **grassland**, 2.0 ha of **meadow orchards** (*Streuobstwiese*), 10 ha of **biotopes** including 0.4 ha **PC demonstration site**. **Main arable crops**: wheat, spelt, rye, oats, clover grass, alfalfa, **Meadow orchards**: apples, pears, cherries, plums, mirabelle plums, mulberries, sweet chestnuts. Agricultural **wild herbs** protection on arable land:, approx. 25 Red List species. **Animal husbandry** (figures on average): *Angeln* cattle – 70 dairy cows, three breeding bulls and their offspring; *Bunte Bentheimer* pigs – eight fattening pigs; *Hungarian Racka* sheep – 30 ewes; Old German herding dog (*altdeutsche Hütehunde*). **Output** (main): dairy herd's average milk output (exemplary year 2022) 4,500 kg including 5% fat and 3.5% protein. **Processing** of food for own consumption and visitor catering: butter, yogurt, cream cheese, bread from natural sourdough.

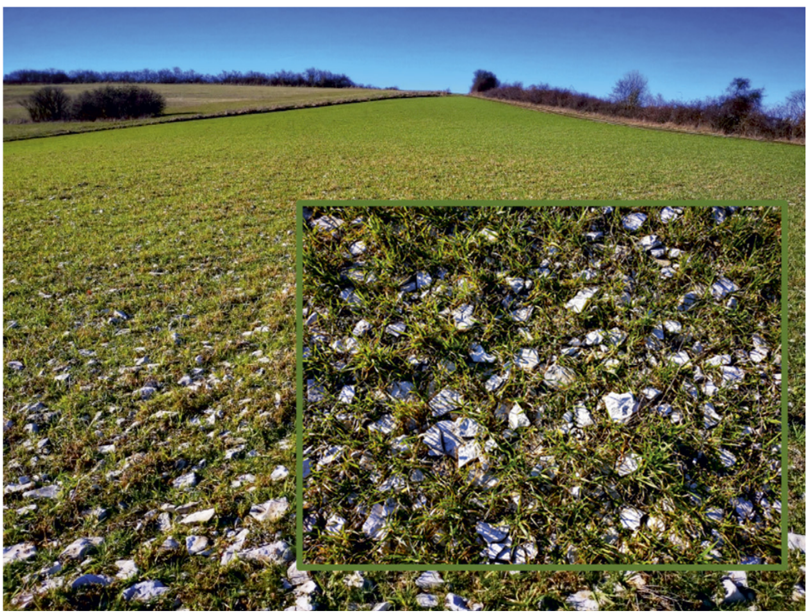

Fig. 4: Agricultural wild herbs protection area on leased land, 15 km from main farmland. Up to 25 Red-listed species have been found here according to the farmer. (Photo: Immo N. Fiebrig; 1 March 2023) ⏎

[242] *Bodenpunkte* (BP) is a quality indicator of arable land, also known as *Ackerzahl* or *Ackerwertzahl* (AZ), with a scale from 1 (very bad quality) up to 100 (very good) (Blume et al., 2016; p. 526 and following). Starting from the 'soil value' (*Bodenwertzahl* BWZ), it takes into account climate or landscape characteristics such as slope or shadows resulting from adjacent woodland.

[243] *Bioland* is a German private-label organic farming standard and certification scheme.

4.1.2 Salient PAs

The most salient PAs that can be identified on the Luna farm system are: **agrobiodiversity**: large diversity of fruits in orchards, diverse vegetables in PC garden, and diverse grains on arable land, plus landrace conservation and breeding according to GEH standards; **wild biodiversity**: increase of bird species as a bioindicator in the area of the farm – up to 60 species according to a recent survey conducted by a bachelor student using a territory mapping method (Paul, 2021). The researcher had conducted a nine-week monitoring on four separate sections of land of similar size (1.3 ha each) but differently structured: (1) a PC garden, (2) agroforestry section (orchard plus hedgerows), (3) an extensive conventionally managed land next to woodland, and (4) an extensive conventionally managed arable open country section. The results show a higher abundance of birds and species in structurally rich sections with a positive effect on the avifauna. An increase in insect populations is assumed but has not been surveyed; **soil cover**: with permanent grassland and the management of 'agricultural rare and endangered weeds protection,[244] constant soil cover is granted, together with the adequate management of arable land through shallow tillage; crop rotation is not allowed, grain needs to be seeded every year and plowed under; **soil structure**: grazing animal densities are kept moderate. The cow landrace *Angler* is relatively light in body weight (300-500 kg), thus minimizing soil compaction; **tillage**: generally as shallow and conservative as possible (low tillage); and **compost/humus**: wood chips from hedge cuttings are mixed with liquid manure and spread on the soil together with solid manure.

The current challenges for the farm are finding an adequate successor to the farm and keeping it economically viable under the market pressures: (1) inflation and increased food prices on one hand, versus (2) high workloads requiring very diverse know-how under decreasing incomes on the other.

4.2 Kiliani Farm, Lichtenau, Germany: Ridge Cultivation

The farm produces grain and vegetables for human consumption and keeps no animals. It is a typical German '*Aussiedlerhof*', a post-war farm resettled from the nearby village – where it had become too crowded – to the outskirts (1967). It is run by a fifth generation, after a takeover by the current farmer in 1985, converted to organic farming in 1989 according to EU-organic production-regulations, and complies with the Gäa e.V. certification scheme (Gaea E.V. Oekologischer Landbau n.d.). The most salient practice on this farm is the management of arable land in 'ridge cultivation' on soil that would otherwise not be particularly suitable for growing vegetables due to its high content of clay. Ridge cultivation, also known as 'ridge tillage' or 'raised bed cultivation', is said to be successfully practiced in conventional agriculture with asparagus, potatoes, carrots or strawberries (LOP, 2016; Müller, 2010; Schlinker et al., 2007), as previously reviewed by Lal (1990) who describes ridge-tillage using mounds or hillocks as saving labor by better weed control, enhancing soil fertility and soil depth, and reducing erosion, thus improving water management. It even allows multiple cropping. The farmer calls his system *Frost-Böhner-Dammkultur*, making reference to Peter Frost, the engineer who developed the cultivation machinery jointly with farmer Hartmut Böhner, transliterated here to 'ridge cultivation technique' or 'RCT' for short.

4.2.1 Farm Profile

Operation: The farmland (see Table 2) is approx. 135 ha arable land, which is made up of **main crops**: 50–60 ha **field vegetables** comprising mostly leek (Fig. 5) and various types of cabbage

[244] The farmer believes this biodiversity conservation scheme is not ecologically sound and could be improved. However, he decided to take part and comply with the authority's requirements to safeguard the economic viability of his business.

Table 2: Basic farm profile of Kiliani Farm ⏎

Farm name	Geographical location	Area, ha	Soil type	Climatic conditions		
				AAT (°C)	AAP (mm)	AMSL (m)
Kiliani	Germany (North)	135	45-50 BP German Index; Luvisol on weathered limestone or marl	7.2-7.5	1,200	300-350

Full-time family-owned business; staffing: one permanently employed in office; two permanently employed for outside work during the season, 25 specialized seasonal workers on fixed term contracts.

Marketing: regional self-marketing via owner-operated food retailers, i.e. large supermarkets at competitive prices which makes organic food accessible to anyone and not only to upmarket customers.

Main income: vegetables.

Fig. 5: Weeds ('wild herbs') managed in the valleys of the leek ridge cultivation. Top: earlier stage, bottom: stage shortly before winter harvest. (Photo: Hartmut Böhner) ⏎

including broccoli; 8–10 ha of sugar beet; 20–23 ha of grain legumes, of which 50% are broad beans and 50% peas; **arable**: 50–60 ha of spelt (Figs 6a and 6b); all RCT crops are either combined with nurse crops such as alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), or spontaneous vegetation, such as typically *Veronica* species, *Anthemis* species, or chickweed (*Stellaria media*); **mechanization**: a tractor pulling three different kinds of cultivators (purpose built for ridge cultivation by Frost Engineering GmbH), (1) for basic tillage (see Fig. 7), (2) for ridging and

Fig. 6a: Typical RCT cultivation of winter spelt sown in keyline as 'double row on ridge', here in early spring (2 March 2023, long shot), with spontaneous vegetation in between ridges (close-up). (Photo: Immo Fiebrig) ⏎

Fig. 6b: Spelt cultivated on ridges; the undersown clover will show up later in the season, offering food to sheep after the spelt harvest in summer; eventually, any remaining biomass is allowed to compost. (Photo: Hartmut Böhner) ⏎

Fig. 7: Cultivator pulled by lightweight tractor (3t) with either a medium or a wide set of tires depending on load (i.e. 30/28 cm rear/front or 50/38 rear tire diameter – in this case, 38 in, which in principle, is the maximum diameter possible, depending on tractor construction, for basic ground preparation in spring), tire pressure 1.2 to 1.5 bar, track width 1.60 m, working width 3.20 m, row spacing 80 cm. Support wheels on the cultivator only have a sensing and balancing function. On such a large scale, the farming is a balancing act between the high-impact planting, care, and harvesting techniques vs. soil compaction. As opposed to small-scale agriculture (e.g. market gardening), in fully mechanized vegetable growing it is virtually impossible to operate without any collateral soil compaction. [Photo: Hartmut Böhner (long shot)/Immo Fiebrig (close-up)] ⏎

ridge seeding, and (3) for weed management, special maintenance and care, for example for the planting of (leek) seedlings; **output**: vegetables for industrial processing and for the fresh food market; grains sold to mills for food production (flour); **processing**: organic sugar beet syrup, a niche product sold b-to-b only, to organic bakeries under the label of '*Lichtenauer Sonnentau*'.

4.2.2 Salient PAs

Kiliani Farm covers all core areas of the PAs, i. e. water, soil, and cultivation. **Beekeeping** is not practiced, but the farmer confirmed that it would be perfectly complementary, especially if surrounding farmers convert to organic farming too, as is increasingly happening. He states an observed (but not quantified) abundance of pollinators such as wild bees and bumblebees. **Seeds**: adapted to the local conditions – he optimizes seeds from one generation to the next (grains); special nature-based preparations are not used but the farmer admits that finding a way to improve the 'mental and spiritual connection' with the plants could increase the yield by 20 %. Overall, it can be said that the **RCT management covers all PAs**. The farm is situated in a windy low mountain range with heavy, clayey loam soils; ridge cultures are prone to erosion by heavy rainfall. Shallow cultivators (duckfoot share) are unsuitable here because they tend to close the pores of the soil and prevent rapid water absorption. Deep cultivators are used instead, along the keyline where possible and appropriate, and the depth of cultivation is established before each cultivation, according to soil compaction, using a copper spade or a soil probe. **Compost application** is performed *in situ* to grant a continuous nutrient supply to soil biota, incorporating mulch from spontaneous vegetation and dry chicken dung *into* the ridges, thus minimizing N emissions. Such an application is only possible with large-scale technology and is preferred here over liquid manures. Compost materials are sourced by bartering from neighboring farmers against straw or grass-clover. In his view, covering freshly prepared ridges with mulch promotes localized composting; aerobic microbial processes are promoted and soil life thus not compromised with RCT. Ridges are assumed to create a microclimate with reduced on-ground wind speed and a rapid warming of the sun-facing side of the slope, thus creating a temperature and habitat gradient in the ridge. Well-managed soils create a water-stable crumb structure (Fig. 8) considered to represent a healthy soil rich in mesofauna (Porre et al. 2016). Böhner estimates that RCT on his farm has helped increase the earthworm population to 400 worms per m^2 of soil (LOP 2016), although no formal study has been conducted yet to support figures. Green manure and spontaneous vegetation keep the **soil covered**, once grains or vegetables have been harvested. Irrigation systems are not existent on the farm: process **water** for pre-washing the harvest is produced largely on-farm, from rooftop collection and recycling via a plant-based wastewater treatment, followed by a rinsing process with potable water. **Agrobiodiversity** is supported to a limited degree by a three-field crop rotation, for example head cabbage – leek – spelt. Apart from the soil mesofauna, **wild biodiversity** is promoted by the existence of spontaneous vegetation as mulch all year round, thus creating insect habitats and attracting birds, in particular larks (family: *Alaudidae;* see related story in book by Busse (2021): chapter 11) and partridges (family: *Phasianidae*). Following cultivation of three hectares of land, Böhner counted 31 kites (genus: *Milvus*) in one instance. Overall, Böhner believes that the management of wild herbs (weeds) by RCT is as effective as conventional plow furrow or herbicide use such as glyphosate but without its detrimental, ecocidal effects. Weeds are gently cut off from within the furrow and covered by soil, thus acting like a small in-situ compost heap that starts fermenting immediately (LOP 2016).

Fig. 8: Example of soil structure surrounding leek after scooping it off the ridge with a spade in early March. (Photo: Immo Fiebrig) ⏎

4.3 Organic Meadow Orchard Stöckl, Rohr, Germany: Apple Juice and Geese

This family-owned side business is a typical town farm, taken over by son Georg Stöckl from his parents in 1988, when it was still run as a piglet production and pig-fattening farm together with laying hens and broilers at the time. Georg studied Agricultural Engineering at Technical University München in Weihenstephan and decided to continue his career in the civil service, becoming Head of Structural Rural Development within the regional Food, Agriculture and Forestry Department of Lower Bavaria ("*Zwischen Wachsen und Weichen*" [Between growing and giving way]) in 2008 and also teaching at the affiliated agricultural school where most of his steady income came from. Stöckl farm lies at the periphery of a region listed as the world's largest contiguous hop-growing region, *Hallertau,* (Burghardt 2021; Braungart, 1880) and known for its asparagus production. By 1996, the farmer's piglet rearing and pig-fattening business was reduced to organic certified pig fattening only and operated until 2001, then given up due to difficulties in marketing and decreasing profitability. Laying hens were introduced instead and the farm was by-and-by converted to a system of meadow orchards requiring less labor, at first with a planting of 1.5 ha of apple trees and linked to an initial business model of "rent-an-apple-tree" offered to the consumer. By 1999/2000, this model was abandoned and the farm became certified to organic farming standards (EU/*Bioland* association). The available land was extended by lease of existing meadow orchards, generally including hedges; additionally, apple trees were newly planted or replanted as a collaborative project on private land. In addition, in 2006, the Stöckl family started the seasonal farming of 100 geese (once a year), on defined sections of orchards. The farm was formally handed over to Georg's son Lorenz and his family in 2020, to warrant a smooth and sustainable transition into the next farmer generation.

4.3.1 Farm Profile

Operation: The farmland (see Table 3) is approx. 32 ha, comprising 31 ha agricultural land (AL), and roughly one ha woodland; 6 ha in ownership, 26 ha leased at a lease rate between € 0 up to € 800.00/ha/year, offset to the land owner against € 40.00 credit balance per newly planted fruit

Table 3: Basic farm profile of Stöckl Farm ⏎

Farm name	Geographical location	Area, ha	Soil type	Climatic conditions		
				AAT (°C)	AAP (mm)	AMSL (m)
Stöckl	Germany (South)	32	50 BP; sandy loam, loess-loam or sandy soil with a share of gravel	7.5-8	750	430

Family-owned sideline business; staffing: family members and occasionally, volunteers around harvest time.

Marketing: direct on-farm sales from shop; juices are additionally marketed via approx. 50 resellers, while produce is also offered as a regional product by other farm shops, organic food retailers, supermarket chains, and beverage shops within a radius of 30 km; in 2018, apples were delivered to the '*r e a l.-*' supermarket chain (retailer) in boxes of 10 kg each. The experience showed that apples would have needed to be prepacked, because the damage from customers selecting apples by feel-up became substantial. The supply was stopped.

Main income: bag-in-box fruit juices. Turnover from all fruit products together in 2019: € 45,000; post COVID recovery 2022: € 55,000.

tree and ongoing management by the farmer; **arable land:** 9 ha grain crops, grass-clover ley and erosion control strips; crop rotation: wheat, spelt, oat/legume mixture e.g. peas, grain maize, and grass-clover ley; winter cereals as intermediate crop for soil cover; **meadow orchards:** 19 ha spread over 25 sites across a radius of 15 km, mainly apples (85%), with additional pears, quinces, and walnuts, showcasing a total of 74 varieties mostly on high stem ("Bio Streuobsthof Stöckl" n.d.); **animal husbandry:** 120 laying hens and seasonally, 200 geese (see Fig. 9); **mechanization**: a specialized mulch mower, hydraulic lifting platform to tractor for pruning and harvesting, two ground fruit collection machines (see Fig. 10 [manual] and Fig. 11 [e-powered]), a collecting

Fig. 9: Late afternoon feeding of geese with apples from the neighboring meadow orchard. Animals are kept separate from the actual fruit orchard for food safety reasons (i.e. Salmonella). ⏎

Fig. 10: Manually driven two-bucket apple picker *Apfel Igel Streuobst Type 800* commercialized by HUEMER, Herbert Huemer, Austria (www.obstsammler.com). Apples are drawn by spikes on a rotating cylindrical drum and stripped off into two standard buckets. Apples need to be processed immediately due to the pinhole injuries caused by the spikes. ⏎

Fig. 11: Manual e-supported cart as one of the experimental fruit collecting machines which Stöckl farm have been co-developing with engineers from Organic Tools GmbH, Austria to showcase mechanization based on e-power, rather than combustion-engines, on farm open days to professionals or the general public, and for educational purposes to schools. Here, apple picking for juice production is shown. ⏎

machine run on fuel, two tractors including standard cultivators (shared via machinery ring) and trailers, a van and an e-car for deliveries, seven hydraulic fruit presses, one fruit washing machine including fruit grating mill, one juice pasteurizing and filling machine, one fruit dryer, and two cold storages for fruits and juices, **output**: fresh (dessert) fruits, dried fruit, fruit juices, jams, eggs, boiling hens, geese; **processing**: apple juice production and apple-mix juices with pear, elderberry, quince, blackcurrant, aronia, or sour cherry; geese are slaughtered off-farm by a contractor.

4.3.2 Salient PAs

In October 2021, the Bavarian State Office signed the Bavarian Fruit Orchard Pact (BFOP) within an eco-model region scheme offering subsidies to farmers, but also including private landowners who are not registered as farmers. According to the BFOP document (*Bayerischer Streuobstpakt* 2021), meadow orchards are a traditional form of agroforestry that developed over hundreds of years within Central European cultural landscapes. The production system is based on (1) strong, tall fruit trees and (2) the use of the understory as meadow, pasture, garden, or arable field. Traditional meadow orchards are considered by the BFOP to be one of the species-richest habitats in Central Europe with approx. 5,000 animal and plant species, i.e. representing hotspots of biodiversity including rare and endangered species. This system of orchards was taken up by UNESCO as intangible cultural heritage in April 2021. The more than 2,000 fruit varieties herein are considered to represent a ‘unique treasure of genetic, tasteful, and healthy diversity’ as issued by the Bavarian Ministry for Environment and Consumer Protection. The undersigning parties therefore agree on the need to protect existing meadow orchards and to create new ones by a catalog of measures (*Bayerischer Streuobstpakt* 2021). With meadow orchards as one form of agroforestry, the farm fulfills one of the main intentions of PC in supporting agriculture strong in the use of perennials. The farm also feeds into local markets by selling directly to consumers, but at the same time without dismissing supermarket chains. This creates resilience in their marketing, while also warranting the sale of larger volumes.

Pasteurization of juices is achieved with energy from wood chips, largely from hedge trimmings. Additional energy is produced from solar panels; local transport and deliveries are performed with an electric vehicle. There is also a strong social component achieved through their public relations activities, such as ‘apple days’ at local secondary schools where pupils are informed about the importance of healthy fruits in their diet and have fun with taste tests and juice making, additionally supported by guided tours of the farm. Together with local institutions, the farmer has also helped to create a ‘meadow orchard nature trail’ on ‘allergy-friendly apple varieties’. Due to the external income of the farmer, now receiving a state pension, the economic viability of the farm has been stable and it has been possible to pay the minimum wage, including social security contributions, to any paid workforce. The subsidies derived from the BFOP and other schemes help the farmer expand his business and secure its existence for the next generation. A payment scheme covering professional fruit tree pruning would, however, be very welcome to improve both orchard productivity and longevity of the trees.

In terms of the PA, both **agrobiodiversity** and **wild biodiversity** are supported within the hedge-lined agroforestry system, including deadwood mounds (‘**insect habitat management**’ including wild pollinators), and constituted by traditional fruit varieties. **Soil cover** is maintained on the orchards all year round and meadows are managed partly by mowing and mulching (‘**compost management**’), and partly by animals (geese) feeding on the grass and drinking from water points (‘**water management**’) which in turn create a wetland microclimate. Arable land is managed by crop rotation and continuous **soil cover** is achieved via additional catch crop cultivation. Meadow management is achieved by cutting or cutting/mulching of the grass in intermittent stripes of 1 m, leaving sufficient un-cut grass for ecologic and economic reasons by: (1) saving labor, (2) leaving habitat for insects, and (3) cut stripes, especially close to young trees, increase the hunting pressure by raptors on mice, pushing them away from managed areas. Old grass stripes are left until winter, so vehicle lanes are thus kept to a minimum.

In summary, as viewed by the farmer [April 2023], “long-term sustainability of meadow orchards can only be achieved by sustaining a fair minimum producer price for apples of € 0.30/kg for cider fruit and € 1.00/kg for dessert fruit. Current retail prices for dessert fruit run at € 2.20 to 2.50/kg and with current profit margins claimed by traders, they tend to make the fresh fruit business unattractive to producers. I achieve up to € 4.00/kg in organic ‘fruit & veg’ box schemes or else I go for secondary marketing of apple sauce or dried fruit, but this is rather a compromise solution and ultimately deprives the customer of fresh and healthy fruit, which runs aside to my original intention.”

4.4 Salmsein Biohof, Völs, South Tyrol, Italy: Integrated Alpine Farming

The roots of the organic Salmsein Farm go back to the Middle Ages, according to the farmer. On the main entrance door of the farmhouse one can appreciate an original engraving from 1559. However, the farm is said to have been mentioned as early as 1420, initially defined as *Schwaighof*, a Middle High German term for dairy or livestock plus arable farming run as a ‘manorial undertaking’, and later passed on to become the property of a monastery.

For 200 years, Salmsein farm was in the possession of the same family, run since 1954 by Josef Kritzinger as granted by the ‘hereditary farm certificate’ and regarded as an example of faithful adherence to a traditionally inherited peasant property. After graduating from agricultural school in 1992, Josef’s son Martin took over the business, and he runs it to this date. Farm buildings are situated partly within the scenic Nature Conservation Park *Schlern-Rosengarten* of South Tyrol (*Trentino-Alto Adige*). The farm grounds its economy on ‘farm stay’, a combination of certified organic production (A-B-CERT[245] from 1997-2023, and ICEA from 2023) – including plans to improve their pond-based, sweet-water, organic-certified aquaculture (carp, trout, tench, eel) – with apartments rented to tourists all year round. The self-catering apartments are made from materials like wood, lime, clay and other natural construction materials. Farm products are sold at the farm shop to any visitor. Additional forestry products and craftsmanship services are offered to enhance economic resilience and success.

4.4.1 Farm Profile

Operation: Farm **structure** (see Table 4) comprises several enterprises: farm as 'one-person enterprise', forestry enterprise, dog breeding enterprise, accommodation business, wood sales, building and excavation business; **farmland**: 26 ha of agricultural land, of which 3 ha are of grassland, based on lucerne (*Medicago sativa* L.), 3 ha of pasture (grazing only, cattle, sheep, and occasionally, horses from neighboring farmers at 1.5 livestock units LSU per ha), 9 ha meadows (mowed for haymaking two to three times, grazed once at max.), 10 ha of woodland, 1 ha pond; **alpine pastures**: 30 ha, of which 10 ha are mowed *and* grazed; all-free range **animal husbandry**: non-tethered housing: 25–35 livestock units of cows/calves, oxen/bull kept on alpine pastures during summer and on pastures around the farmhouse during transition and winter, (including a free-range barn according to the newest animal welfare standards); goats, sheep, laying hens, ducks, geese, rabbits, guard dogs; **output**: fresh and smoked meat, timber, farm stay (tourism), building, excavation, and forestry service; **processing** of bacon from beef – the son is currently doing a butcher apprenticeship; liquor production; **special feature**: a pressure irrigation system built in 1954 and upgraded for emission-free (injection) slurry application.

Table 4: Basic farm profile of Salmsein Farm ⏎

Farm name	Geographical location	Area (ha)	Soil type	Climatic conditions (farm and mountain pasture, MP)					
				AAT (°C)		AAP (mm)		AMSL (m)	
Biohof Salmsein	Italy (South Tyrol)	26	Sandy soil improved by porphyr	Farm	MP	Farm	MP	Farm	MP
				7.1	4.5	650	1050	1,000	2,200

Full-time family-owned business; staffing: family members.

Marketing: Direct to consumer (holiday guests amongst others) from on-farm shop, including organic produce from neighboring farms; gourmet restaurant supplier.

Main income: Farm holiday stay and forestry service provision.

4.4.2 Salient PAs

Beginning with '**water management**' as a starting point on this farm, Salmsein has developed a system of nutrient recycling via its underground, solar energy-driven sprinkler irrigation system (13 ha around the farm house). Slurry that has been accumulated in the free-range barn during winter is processed through a centrifuge, whereby the aqueous phase is separated and injected into the irrigation water in small but continuous doses. The solid phase is put to compost and used as fertilizer in arable farming – here, even if not for market, seeds are selected (the largest ones) and saved, thus contributing to the agrobiodiversity of locally adapted species. The liquid-pasture fertilization can be applied during the growing season (spring, summer) or any other time as long

[245] Certifying body A B CERT GmbH

as the system is not frozen (winter). Application is considered emission-free, independent of the vesting periods for manure application, allegedly produces no air pollution like smell and methane, nitrate-leaching is minimised, soil life is not burdened by sudden and toxic manure loads, and soil compaction is kept to a minimum (no driving lanes from tractors), which is thus assumed to contribute to soil life and thus to **soil structure**. Diversity of farm produce is provided by the wide range of different animals raised. Economic resilience is granted by diversifying service provision and products. Energy supply is produced on-farm (photovoltaic) for hot water supply and heating, with any surplus going into the grid, and including a supply for electric vehicles (see Fig. 12). There used to be a biogas plant producing electricity from 1997 until 2007. However, production ceased because of the decrease of feed-in compensation on the one hand and the takeover of food waste from local hotels by a public company operating free of charge.

Fig. 12: Alpine pasture management with battery-powered mower. ⏎

In summary: A major challenge to the (economic) sustainability of farming activities is based on the interests of the municipal administration in conflict with the interests of the farmer, within the set power difference. Examples of such public/private conflicts include (1) a retroactive withdrawal of the permission to raise pigs in woodland; (2) the competition for water for recreational water bodies related to tourism – and the farmer's needs for water bodies: animal husbandry, recreational fishing, or paying guests; and (3) the municipal promotion of tourist paths through farmland – based on customary right – and subsequent regulatory demands to the farmer regarding safety and insurance, which proves costly to him and is adverse to his farming activities.

5. Discussion

'PC as a concept', following the emblematic 'permaculture flower' around ethics and design, is arguably the most comprehensive sustainability vision devised so far, with its 'seven domains of permaculture action': (1) buildings and the built environment, (2) tools and technology, (3) education and culture, (4) health and spiritual well-being, (5) finances and economics, (6) land tenure and community governance, and (7) land and nature stewardship (Permaculture Flower

2013). Most PC teaching is typically geared around designing a productive system of agriculture, forestry, and livestock, in theory and with the aid of a base map plus extensive group and expert discussions – i.e. designing a productive system for self-sufficiency and for the provision to local markets, with sustainability in mind. This may be with the aim of building a 'circular economy', powered by a group of like-minded people (for example 'co-housing/co-working'), often on barren (degraded) land, with the intention to regenerate the ecology and the socio-economy of the place. There is little doubt that 'PC as a movement' spread grassroots from Tasmania by some effect of feeling 'inspired' to action, mostly, at least during its inception, without any support from public entities (cf. Fiebrig et al., 2020). PC as a concept creates an openness, an awareness to change one's life and life-style. And it has inspired both farmers and people with non-farming backgrounds who are intending to achieve more satisfaction in life. PC can be life-changing (Fiebrig et al., 2020). Published academic research around 'PC as a practice' has taken different approaches, for example: examining the socio-demographic aspects of 731 international 'permaculture participants'; in terms of gender or ethnicity (Ferguson and Lovell, 2015), or as a farm typology and livelihood analysis of 36 self-identified PC farms in the US, showing that typically, such farms are small and recently established, mostly run by young and new farmers, and fitting the definition of 'diversified farming systems' (Ferguson and Lovell, 2017).

Researching emergent PC farming activities in Europe on farms whose PC characteristics and related practices are fundamentally eclectic seemed challenging. In order to harness this challenge, we had first taken an approach through 'sustainability assessment', showing that the employed assessment tool had been helpful to engage with the farmer to begin with and to get to know the farming business through a semi-structured interview process preceded and/or followed by a farm walk. In a brief digression, we give an insight into the sustainability assessment work on permaculture farming systems below to complete the discussion.

5.1 Holistic Sustainability

Mészáros (2016) made an evaluation of several tools, concluding that one of the most holistic tools is the 'SMART farm assessment tool', which she chose to conduct research in Hungary to compare organic and conventional farms for her master thesis. She assessed 25 farms of both farming systems and concluded that organic farms had better sustainability performance in most areas. She also emphasized that organic farms performed significantly better where the farmer converted to and maintained organic farming because of conviction and belief, not for economic reasons alone (Mészáros, 2016).

Following her work, Szilágyi performed another exploratory study in Hungary and in the United Kingdom for his master thesis using the SMART farm assessment tool to compare conventional, organic, and additionally, PC farming systems (Szilágyi, 2017, 2018, see study details in the appendix section 7.5).

It was found that the sustainability performance of conventional farms is clearly inferior to the other two systems studied (Fig. 13). The performance of organic and PC farms is almost identical regarding the 'social well-being dimension', whereas PC farms perform better specifically regarding 'local economy and investment' within the 'economic dimension'. Organic farms underperformed PC farms in all themes of the 'environment dimension' and the 'good governance dimension'.

The restriction on the use of synthetic fertilizers and plant protection products both on organic and PC farms contributed largely to the results in the SMART scoring. This was especially so on PC farms, where reduced soil cultivation (often no-till), mulching, and other soil management techniques improved the results as opposed to conventional farms. Biodiversity measures and agrobiodiversity on these farms were also key, thereby indicating sustainability within relevant themes. Results of the socio-economic and management assessment pointed out that organic and PC farms (or their farmers, to be more specific) were in general more open-minded, socially sensitive, conscious of

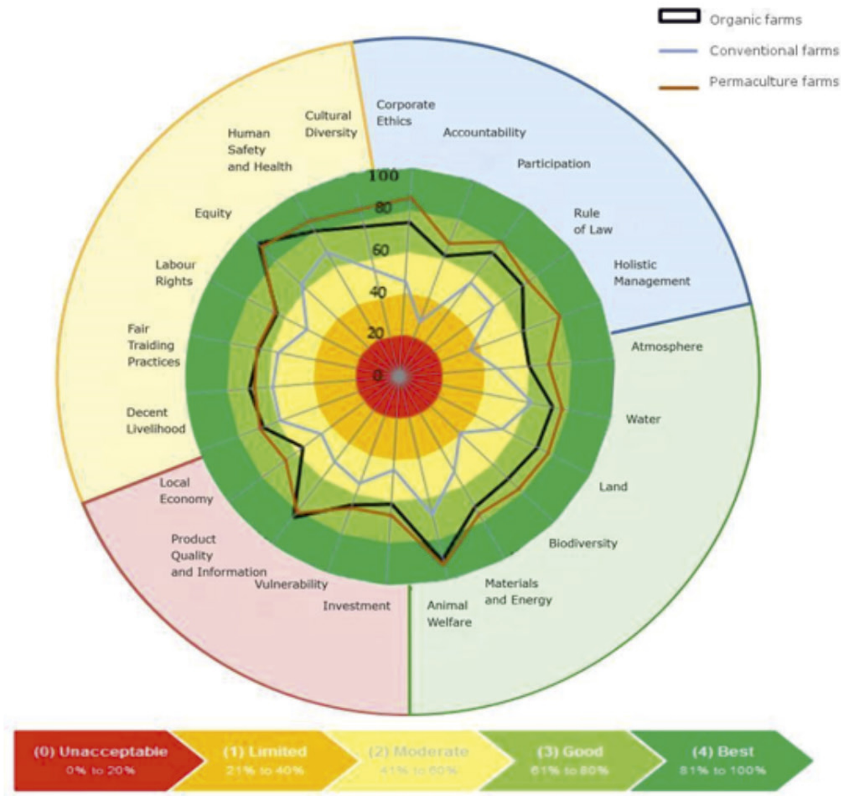

Fig. 13: Average sustainability performance of conventional farms (n = 13), organic farms (n = 18) and PC farms (n = 20) by themes. (Original figure from Szilágyi, 2017) ⏎

marketing strategies, and of the importance of short supply chains; they seemed more innovative in attitude and interested in public participation.

It has to be pointed out here that SMART assessment results are by no means to be taken as 'absolute truth' as to sustainability. Results are to be taken with caution and as indications for further studies. They can, however, give an indication about both the strengths and weaknesses of an assessment tool and of the farming systems studied. Furthermore, farming traits that are particular to permaculture may not be adequately valued and evaluated by the currently existing holistic sustainability tools. For this to happen, a prerequisite would be necessary to further define and study these particular 'permaculture farming traits' and define their contribution to holistic sustainability in practice.

5.2 Current Challenges and Limitations

PC farming for the market entails additional risks such that the socio-economics of such farms may turn out weak in spite of the ecological strengths. Cultivated heirloom varieties, for example, may look 'ugly' to the consumer's eye, which is used to uniform sizes as well as perfect shapes and surface coloring and textures. Also, their shelf life may be significantly reduced and availability may be limited due to a short harvest period, making short supply chains for fresh produce crucial. Production for local consumer markets and regular customers is one solution. Direct on-farm marketing, community-supported agriculture and marketing via crowdfunding platforms can also help to solve these challenges. Other PC farmers may resort to the on-farm processing of fruits and vegetables to more durable products like jams, chutneys, juices, syrups, or schnapps and consuming any fresh produce themselves, within family and friends. However, the prevailing experience of 'too much work – too little profit' compromises the existence of many PC farms, as is the case for many other small-scale farming systems, making it difficult to pass the business on to the next generation, unless politicians, institutions, and the general public with its voters understand the losses before they become irrevocable.

5.3 Future Potential

In future, PC farmers would need to be rewarded for their supposed higher degree of sustainability, thus creating incentives on a more rational basis in favor of sustainable farming systems and leading to disincentivizing bad practice. Where sustainability assessment tools are used to objectivize benefits and turn them into rewardable ecosystem services, particular practices in PC need to be studied and evaluated further, such as organic mulching, biochar application, keyline design, the application of 'fermentation brews from beneficial microorganisms', biotope reconstruction via ponds and lakes, or water management with swales. Studies on costs versus ecologic and socio-economic benefits are still lacking. In ecological terms, one of the key values of PC farming systems may be the – priceless – conservation of live agricultural biodiversity and agricultural ecology, aside from artificial seed vaults.

On the 'social' side of sustainability, the value of an assumedly inspiring holistic concept like a PC design may also still be undervalued. For example, what is the value of interactions in terms of networks and support systems, outside of governmental institutions, keeping farmers in a resourceful state of mind and away from a feeling of helplessness? A Dutch NGO, the Commonland Foundation, dedicated to "bringing people together to restore degraded landscapes", has shown several links to PC through their stories (e.g. "Using Permaculture to Design for Resilience and Regeneration") and their advisory board members (e.g. prominent permaculturist Geoff Lawton, ["Team" n.d.]) or NGO collaborators (Permacultura Mediterranea, PermaMed). Commonland's principle of 4 returns states the 'Return of Inspiration' alongside social, natural, and financial returns (4 returns framework n.d.). Due to the diversification experienced in PC, the running of a farm is knowledge- and workforce-intensive. The social role of PC farms in providing teaching places and environments where farming students learn and socialize is not to be underestimated. They may include jobs for those who find it difficult to find occupation in conventional working environments due to the performance limitations from burn-out or any other disability that benefits from a close interaction with nature and natural processes. Such enterprises, so far, have to rely on steady public subsidies and grant money.

5.3.1 Permaculture and Arable Farming: RCT

Fillippi (2013) had discussed whether arable farming can actually, in principle, be considered part of a 'permaculture'. In his article he concludes: "*Permaculture needs to be far more focused on bringing its principles to the field, rather than on a wholesale conversion to […] perennial plants, which is neither desirable nor necessary. Whilst permaculture should definitely involve the intensive planting of edible hedges, orchards and woodlots, as well as various forms of silvopasture and agroforestry, it needs to, first and foremost, offer a critique of arable farming, both pre-industrial and modern, without promoting its abandonment.*" We suggest that Böhner has indeed brought permaculture principles to the field by implementing the Ridge Cultivation Technique (RCT). He believes that the RCT can be a real 'chemistry-free agriculture' alternative ([Ger.] "*chemiefreie Landwirtschaft*") with yields comparable to conventional agriculture which still relies heavily on synthetic pesticides, including herbicides, and fertilizers. Preliminary results from self-funded research suggests this with RCT-grown wheat (Böhner, 2024). In his exploratory experimental set-up, he compares conventionally cultivated wheat with RCT-grown wheat. His results indicate that the RCT may lead to competitive yields whilst turning away from chemical aids. He admits that more thorough research is very much needed, such as long-term experiments including soil monitoring, and experimental setups with different crops. However, from personal communication, farmer Böhner has found it hard to find funding for such research. Structurally, this may be due to the lack of intellectual property pertaining to industry (for example, proprietary rights on pesticide molecules). One could argue, of course, that the RCT's return on investment would 'pay back' to Nature and mankind as a whole, and not just to a handful of shareholders.

6. Conclusions

One could be skeptical as to whether the very strong ecological and social sustainability principles underlying PC are compatible with being 'commercial', i.e. operational in the prevailing economic systems. Turning the perspective upside down, one could ask what is needed to adapt the current economic system such that, for the sake of planetary survival, it conforms to the principles of PC – an 'agroecology for food sovereignty' – within left-liberal or even more radical narratives. It may thus seem impossible to make PC 'capitalist' without subverting its strong socio-cultural principles. This would entail dehumanizing the labor and livelihoods of many of those working in agriculture, whilst concentrating purely on techno-ecological fixes to 'feed the world' and 'save the climate', maintaining food production as an exploitative undertaking driven by corporate dynamics.

The farms presented herein are more suited to producing regional, specialty food for local markets, including tourism. An 'Economy of the Common Good' (Lindner n.d.) may sound utopian, but might lead to a suitable framework for food production and trade outside of 'commodification' and the stock exchange. Current profit margins of food retailers (supermarket chains) tend to be simply too high to allow a decent living wage to small-scale producers who are inherently providing jobs and a wealth of other ecosystem services that society needs to value and pay for. A reform towards an economic framework that taxes primarily luxury goods – but not human labor (basic wages/salaries) and not basic food – could support this change. So much for socio-political ideas and ideologies.

Regarding applied research, a thorough review of gray literature around PC and its practical applications, possibly aided by so-called Artificial Intelligence (e.g. ChatGPT, HYDRA, Knetminer, cf. Drury et al., 2023), could be an interesting way to sharpen the profile of PC in farming, with evidence of its benefits, often using traditional farming techniques, combined and developed in the context of modern society, modern technology, and current or future ecologic and socio-economic challenges. One of the key values of the concept of PC may lie in its 'inspirational power', inviting farmers to open their mind to change and experimentation. PC's design approach may at the same time support family and group discussion, simulation, and planning of changes and processes in order to minimize risks and maximize benefits. Coming to the end of this treatise, I would like to give farmer Hartmut Böhner a voice for his personal vision about PC and his 'PermaRidgeCulture', as he calls RCT: "*It has shown that crops can be grown more efficiently and with higher yields in a ridge culture. This would apply, in principle, to all crops (except fodder crops: they require a flat structure for harvesting). Actively using wild herbs (weeds) for soil loosening, nutrient storage and compost fermentation leads to my slogan: 'yoke wild herbs to the plough'. At the same time, RCT brings species and environmental protection back into the productive fields.*

However, a major challenge in agricultural landscapes remains the 'existence-threatening co-existence' between conventional agriculture and OA due to pesticide drift. Under such circumstances, pesticide-free food ceases to exist. This was, for example, shown by bark monitoring of airborne pesticides between 2014 and 2018 within the activities of the Association for Grandchild-friendly

Agriculture.[246] *Passive samplers had been set up at over 50 locations in Germany with the result that over 120 active substances were detected and glyphosate was found in every sampler.*[247,248] *Despite all efforts, e.g. drift-reducing nozzles, it is still not possible to get 100% of the pesticide droplets onto the desired target area, regardless of technical progress! The logical consequence is therefore to avoid using 100% of pesticides, not just from one neighboring field to the next, but across entire landscapes or regions by developing PermaRidgeCulture (RCT).*"

Böhner sounds optimistic and appeals to all researchers, especially at universities, to take up the challenge of achieving maximum yields without the use of pesticides but with the help of organic fertilization and RCT. He calls for the worldwide establishment of competence centers. These should research '(synthetic) chemistry-free farming' and provide convincing evidence as well as advisory support to practitioners. In this way, he states further "…*we can slow down the extinction of species, protect water bodies and the air we breathe and create an agriculture producing food that is safe for our grandchildren, in collaboration with the entire human society."*

Böhner's key question is: "*What production can a farmer actually achieve without a 'chemistry kit' at his/her reach"?*

7. Appendix

For the sake of completeness, the appendix that follows gives deeper insights into each of the four farmer's stories and details of SMART sustainability assessments.

7.1 Farmer's Stories

Details of the farmer interviews per farm can be found here, including interviewee verbatim. The aim was to retain details around each farmer's motivations for using PC and inspirations from PC principles, guiding the farm planning, redesign where appropriate, and daily farming procedures.

7.1.1 Farm Luna

Question: What guided change on the farm (towards PC)?
Answer: *"After taking over the farm from my father, I started planting hedges (shrubs) and fruit trees every autumn for the following 10 to 15 years. The aim was to positively contribute towards nature regeneration with improved landscape design. My idea was to protect wild animal and plant species by increasing the ecological connectivity with the adjacent woodland, reduce farmland wind erosion, and promote good water management. The actual beneficial effects on the farm business became apparent only after many years. The PC part of the farm was introduced much later by taking on PC teachers T. and Ch. who started to run the Permaculture Learning Site as part of the German PC Association and as an independent self-sufficient enterprise. It seemed to be the perfect fit. The couple runs PC courses, manages PC gardening and runs the kitchen and bakery to provide the farm's staff and course participants with the food prepared mainly from farm produce."*

Question: What kind of plan or design was developed and how?

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[246] https://enkeltauglich.bio/
[247] https://enkeltauglich.bio/wp-content/uploads/Abstract-Bark-Biomonitoring_englisch_new.pdf [English abstract]
[248] Hofmann et al., 2019; Clausing, 2020

Answer: *There was little specific literature on ecologic measures existing at the time and the effects the hedges would have on the animals were unknown to me then. So, some things came as a positive surprise. To me and the animals (cows) the hedges were some sort of live fencing and I assume that browsing the leaves and branches increased their uptake of micro-nutrients, for example minerals. The cowpats – proper cowpats and not diarrhea-like heaps*[249] *– might have attracted insects, thus providing food for birds. Therefore, bird species returned for nesting. Over the trajectory of 25 years, we noticed an increase in the hardness of the cow's hooves, which I attribute to the more balanced nutrition along with my own breeding efforts on my cows, promoting healthiness and resilience of the breed and to a lesser extent, breeding for productivity. For the last ten years, we have not needed to use the hoof trimmer and productivity losses due to hoof damage have been minimized. This saves up to € 15.00 per hoof trimming and € 40.00 for any follow-up treatment of sores – per cow.*

The return of lost species of fungi on the grassland took the longest. I attribute this to the management of the liquid manure, which was always mixed with other manure and with wood chips from hedge trimmings before it was used as fertilizer to the grassland. My idea, inspired by the concept of terra preta*, was to help increase the humus content in the soil – initially as low as 0.1 to 0.2% SOC. Adding woody material, I believe, has been very effective over the years. The results of recent grassland soil analyses show that SOC has gone up to 6%."*

Question: What are the most salient aspects of PC you implemented on your farming system, ecologically and socio-economically?

Answer: *"Socio-economically, the farming business is not set up to maximize profits. Thus, we largely rely on the enthusiasm created amongst the young as well as elder staff and volunteers. Farm self-catering is achieved through collaboration with the PC Learning Place enterprise, by preparing food and managing the kitchen jointly. This creates a positive working atmosphere alongside the shared meals of healthy food. We also socialize by creating our own cultural and leisure program. People feel well here in the rural area and some volunteers even come from outside the village to socialize and help with working at weekends. Ecologically, as an 'Archehof' farm, our main aim is to preserve rare breeds and improve them. Many animals are subsequently sold for further breeding to other farms. The cows, for instance, are increasingly sought for producing good milk quality which is high in unsaturated fatty acids whilst not needing concentrate feed."*

Farm Luna received the Federal Organic Farming Award (*Bundespreis Ökologischer Landbau)* from the German Ministry of Agriculture in 2020 for innovative ideas and exemplary approaches. Farmer Betram claims he always wanted to farm in a 'good manner' – because this, according to him, is equal to 'good nature conservation' (Schächtele, 2020).

7.1.2 Kiliani Farm

"*The fact that I am an organic farmer today was not at all foreseeable at the end of my studies as an agricultural engineer. During my time as a field technician at university, I was convinced that conventional farming methods were the only way to achieve reasonable yields. I could not picture any growth without chemical-synthetic, nitrogen-phosphorus-potassium fertilization. This opinion of mine changed when 40 students, including myself, founded an organic farming working group, wrested a hectare of experimental land from the university, and farmed it. I had my 'aha' experience after the first harvests were collected: organic field crops grown on heavy clay soils outperformed conventional crops grown on 'good soil' when compared within the contribution*

[249] Farmer's explanation: "Proper cowpats are a result of not offering concentrated feed, but instead giving enough crude fiber and taking care not to offer too much fresh grass at a time, thus preventing diarrhea that will not allow insects to thrive."

margin accounting. What is more, the first time I stood in a spelt field that had grown 1.8 m tall without chemical fertilizer, I felt this had been a 'world wonder'. At the time, I had moved far away from natural processes in my self-concept. Today, I'm glad I was able to switch gears in my mind and leave all the 'pressures' of conventional farming behind. I enjoy the 'sportive challenge' of attaining the equivalent of conventional yields in an organic way" (LOP, 2016).

Question: What guided change on the farm (towards PC)?
Answer: *"I started reading the literature of Masanobu Fukuoka and his natural farming method – 'Do-Nothing Farming' – and searched a reference given to a farm in the Netherlands which I never found! I then got to know about Julián Turiel*[250] *and his dam cultivation method, which lead to a long-standing collaboration. Other sources of inspiration related to PC have been agricultural engineer Marion Buley, entrepreneur Friedrich Lehmann and late Mexican farmer Eugenio Gras."*

Question: What kind of plan or design was developed and how?
Answer: *"Change came about due to deeper insights from observing nature, trying out something new and evaluating the results. Within the discussions between tillage or no-tillage, I rather sought the advantages from* both *practices. Thus, I developed my own system for what is more commonly known as the ('Turiel') ridge cultivation method."*

Question: What are the most salient aspects of PC you implemented on your farming system, ecologically and socio-economically?
Answer: *"Ecologically, I developed a model of plant communities, for example in cereals with the establishment of white clover in combination with site-adapted wild species, thus creating a synergy where the cash crop sits on the "throne", and the synergists are placed in the valley. Socio-economically: I treat my employees with respect and on an equal level; my leadership is by example. If I want to change the behavior of members of my team, I believe in showing how I do the work myself without patronizing. Motivated workers want to know from their employer how things are done and if they see me as a leader doing things, they usually follow it. Any crop that cannot be sold to the market for its looks, for example because of an odd shape or less uniform skin, is donated to a local food-saving charity.*

In summary: "*What is important is mindset. Most of the development has been guided by my intuition. I trust in God, I am in acceptance of the Creator, I am committed and feel spiritually connected, enjoying joint achievements whilst having fun*."

7.1.3 Farm Stöckl

Specialized commercial fruit farms are viewed as one of the most intensive production methods with up to 30 sprays per season, in both conventional but also organic farming, according to the farm's website. These serve the mass market for dessert fruit in wholesale and retail. Some of the fruits are imported all the way from New Zealand or Argentina. Only a reduced number of apple varieties are still on offer to trade. The visual flawlessness and uniformity of the fruit seems to rank far above taste. By contrast: "Our development of the *Bioland-Streuobsthof Stöckl* proves that there is another route to producing apples and that economic success can be achieved nonetheless after a longer start-up period." The first meadow orchards were set up in 1996 on former arable land, in collaboration with various associations and with governmental advice, partly on leased land with a minimum lease period of 20 years. The initial goal, according to the farmer, was to maximize fruit species and varieties thereof. "Only later we learnt that the focus on fewer varieties

[250] www.turiel-dammkultur.com

improved economic success." The ecology of meadow orchards was upgraded by border planting (hedges), *Benjes* hedges (deadwood), clearance cairns, or ponds and water points. Also, through my position as chief agricultural officer, I had gained a lot of experience from other farms in terms of improving organic farm management and economic viability which I could use for my own farming venture and for my teaching activities at the agricultural school."

Question: What guided change on the farm, (towards PC)?
Answer: *"I saw a documentary on Sepp Holzer's*[251] *farm, Krameterhof, on TV and got inspired by many of his books."*

Question: What kind of plan or design was developed and how?
Answer: *"The idea was to run this farm as organic and to refrain from the use of pesticides altogether, whether synthetic or organic sprays. Part of the plan was not to irrigate except for the young trees for up to two years."*

Question: What are the most salient aspects of PC you implemented on your farming system, ecologically and socio-economically?
Answer: *"We created a circular economy producing healthy food which is marketed regionally and became marketing partners to Solidarity Farming, an association where producers and consumers collaborate as a local economic community. Our harvest workers are paid in kind. The farm is also a teaching enterprise used for showcasing organic farming to students from the local agricultural school. Our meadows serve as habitats to geese, offering excellent conditions for animal welfare and very good quality meat. The grain fed to chickens and geese is grown entirely on our arable land. Fruits, mostly apples that are not used for juice production or sold as dessert fruit, are fed to the geese once a day as a special treat. They love it!"*

Outlook: The farmer was planning to expand by: (1) building up a herd of ewes of Shropshire breed for grazing the meadows on a very small scale; (2) setting up an organic meadow orchard sponsorship scheme [Ger.: *Baumpatenschaft*]; (3) growing plots of cider fruits (500 apple trees/ha); and (4) setting up bee-keeping. All of these complementary business activities would depend on an extra responsible workforce which is primarily sought in suitable entrepreneurial collaborations rather than additional wage earners.

7.1.4 Salmsein Farm

Question: What guided change on the farm, (towards PC)?
Answer: *"I have been following the work of Sepp Holzer in the media – TV, video – and reading his books since about 2010, when he was still running his alpine farm. I wanted to know if his success was just about marketing, but understood that one should try and find specific places on the property where, with little effort and without the use of synthetic chemistry, a yield can be obtained. Such places are favorable locations, locations where different plants can thrive. The forest has protected areas, where we still have the potential to practice animal husbandry."*

Question: What kind of plan or design was developed and how?
Answer: *"I started putting alfalfa seeds into the drinking trough; the cows would excrete the seeds via their feces and spread the growth of the legume, improving the quality of feed. I also started adding slurry and lime into the irrigation water as fertilizer and soil-pH optimization. I became more experimental, I tried out different things I had heard of and used common sense, for example planting berries along the edge of the lake, also trees, at the right distance to the shore, so that they would get the adequate amount of ground moisture."*

[251] Sepp Holzer is a permaculture farmer from Austria renowned through his books (see also Fiebrig et al., 2020).

Question: What are the most salient aspects of PC you implemented on your farming system, ecologically and socio-economically?
Answer: *"I diversified my business, not specializing in one thing only; because of the uncertainties with the weather you have to create fallback positions. Also, the dependence on meat and milk prices can thus be mitigated."*

According to the farmer, reflection is usually enough to know exactly what we are doing sustainably and what not, no great philosophy is needed. *"Just use common sense. The business of 'Speck*[252] *Alto Adige' (South Tyrolean Speck) is actually a scandal. As a protected geographical indication (PGI), the consumer would expect the meat used for* Speck *production to be from pork raised in South Tyrol. However, this is not the case. It is mostly imported pork legs from conventional (industrial scale) farming from the Netherlands, or elsewhere, and it is only* dry-cured *here; so it is the place of the specific processing that grants industry the PGI label, not the actual provenance of the raw material. The average consumer won't know. It leaves me speechless when so little common sense is used."*

Farm owner Martin Kritzinger continues explaining his own way of raising pork and producing an authentic South Tyrolean, organic and sustainably produced *Speck*. In 2006, he had been granted permission by the competent authorities to reclassify a section of his woodland to *landwirtschaftliches Grün* ('agricultural green'[253]) with the intention of raising pigs in a habitat most natural to these animals and producing free range organic meat. He set up the system, built fencing and an earthen refuge next to a pond for wallowing. Pigs were able to provide for themselves by, for example, feeding on the acorns from oak trees. According to Martin: "…the perfect place for pig husbandry had been set up. Besides, where fallow land is kept, the ecosystem gets activated and bark beetle pest pressure will be reduced." However, according to the farmer, in 2020, a municipal official unofficially informed him that he had to stop his pig husbandry, in spite of the legally granted permission; this led to the end of this type of farming activity, so far without challenging the statement. The reason given to the farmer was that pasture farming on the boundaries of a natural reserve was infringing current law and that the granted permissions had allegedly been an administrative mistake. Assumptions can be made over the seriousness of this justification, especially within current EU politics that explicitly intend to promote the improvement of animal welfare (Caporale et al., 2005; Molitorisová and Burke, 2022). On the other hand, business-related conflicts of interest over local market shares (tourism) or even (private) conflicts of interest over the acquisition of family-owned land may influence local politics. This is particularly so in such small rural communities, where an imbalance of power between private farmers and local governance, including rather personal resentments between stakeholders, may play a significant, and at the same time hidden, detrimental role towards more sustainable farming (see for example Landolt and Haller [2015] regarding alpine common property in neighboring Switzerland).

The farmers vision: "…Towards more natural cultivation and production without [ed.: synthetic] pesticides, food with healthy value, more understanding of nature and experiencing nature, towards a cultural landscape where the tourist, guest, and hiker feels good and is not frustrated by toxic smell, more protection of resources such as water, air and diversity of flora and fauna, and towards a production system in which the next generation still has a good chance of managing."

7.2 Farm Sustainability Assessment

This section of the appendix gives background details on farm sustainability assessments comparing conventional, certified organic. and non-certified (self-identified) PC farms. The assessments

[252] German term for 'bacon'.
[253] Reclassification of land is managed in accordance to the regional regulations specific to fragile ecosystems and nature-protected areas like *Schlern-Rosenpark Südtiroler* (Landesgesetz, 2018): 'agricultural green' is agricultural land entailing reduced building activity.

represent an exploratory attempt to concretize the differences in outcomes, comparing OA and PC farming, with conventional farming as a system of reference. Since developing frameworks for defining sustainability in agriculture, several indicator sets have also been developed for measuring and assessing practices and many tools have been created to operationalize the assessment procedure (Wustenberghs et al., 2016). The parameters and methods for how the qualities of sustainability in agriculture are actually objectivized, i.e. measured and assessed in practice, still run with numerous challenges (De Olde et al., 2016a and b). Adapted approaches in tool development and assessment practice have been forthcoming, some addressing pressing practical issues to evaluate the farms‘ *status quo* and potential progress to be made to improve sustainability (Alaoui et al., 2022; Ness et al., 2007).

The methodological developments of sustainability assessments have been ongoing in academia since the 1990s – with separate disciplines having been established for the topic, such as ‛sustainability metrics' or ‛ecological indication' – becoming a platform for the necessary interdisciplinary discourse (Gasparatos and Scolobig, 2012). One concern in tool development is the need to cover an increasingly holistic view and provide a ‘full picture' overview of the system's quality, for example nature's ecology, human's socio-economy and its governance, adapted to the scale of assessment – from parcel or farm level to region-specific-scenario assessments (Schader et al., 2014).

7.2.1 SAFA as Entry Point

The UN Food and Agriculture Organization (FAO) had opened a new chapter in evaluating the sustainability of agriculture and food production with the development and publication of the Sustainability Assessment of Food and Agriculture Systems (SAFA) tool and guidelines first presented in 2013 (FAO n. d.; FAO, 2014). Taking into account the many different interpretations, tools, and methodologies, the FAO made a ground-breaking attempt to create a consistent framework involving many expert opinions to designate which topics should be measured in relation to the sustainability of agriculture. The SAFA framework defines four dimensions (Good Governance, Environmental Integrity, Economic Resilience, and Social Well-Being), and 21 themes with 58 sub-themes covered by a total of 116 indicator items. For example, within ‘Environmental Integrity', the theme ‘Biodiversity (E 4)' with the sub-theme ‘Ecosystem Diversity (E 4.1)' assesses ‘Ecosystem Enhancing Practices (E 4.1.2)' asking for the evaluation of implemented activities and practices that have "effectively enhanced the functioning of ecosystem services as well as the connectivity of ecosystems" (FAO, 2014, 129), such as "land cover and land-use change to more structurally complex and species diverse systems, such as agroforestry, mixed crop-livestock systems, mixed rice-fish systems, intercropping, perennials, forest gardens, etc…" (SAFA Tool version 2.2.40; Fiebrig et al., 2015). The holistic sustainability assessments presented here were developed further, on the basis of SAFA, allowing for better contextualization and including a definition of intermediate scores: ‘SMART' (Sustainability Monitoring and Assessment RouTine; Landert et al., 2020).

7.2.2 SMART Farm Assessment Tool

The SMART farm tool, which has been developed by the Swiss organic research institute (FiBL) to cover all sustainability aspects outlined by FAO, integrates more than 300 indicators to provide a holistic assessment (Schader et al., 2016; FiBL – SMART n. d.). SMART is based on the extensive literature that was used to develop the previous, still somewhat less operationalized but holistic,SAFA tool as a starting point (FAO, 2014). Furthermore, SMART contextualizes farm assessments according to farm typology and the scoring of individual responses to questions is based on extensive expert appraisal built into the SMART evaluation process.

7.2.3 Farm Selection

Farm selection was to a large degree arbitrary and served to operationalize an exploratory study assessing the suitability of SMART assessments in the context of PC farms. The study was performed in Hungary and in the UK, both European countries but with very different economic and political backgrounds; the choice of countries was based on practical reasons. In both countries, PC farms were selected from established PC networks (Magyar Permakultúra Egyesület [permacultura.net; https://permakultura.hu/en/map/], Permaculture Association UK [www.permaculture.org.uk/projects-and-land-map] with the prerequisite of producing for the market and not for self-sufficiency only. Farm visits were planned according to the willingness and availability of the interviewee on-farm and the driving distance by car (limited to no more than three hours), as well as the possibility to combine farm assessments together into one or two assessment trips to minimize use of resources. Organic-certified farms and conventional farms were recruited from farmers' markets close to the residence of Szilágyi.

7.2.4 PC Farm Assessment Study

All of the SMART farm assessments within the study were based on a farm visit consisting of a tour of the farm and a face-to-face questionnaire survey by auditors trained on SMART (theory and practice) at FiBL. The interview took around 1.5 to three hours depending on the complexity of the farm and the openness of the farmer. The field audit took an additional 1-2 hours, where some of the indicators (e.g. animal welfare indicators) were assessed in detail by the auditor.

The SMART questionnaire comprised the typical sustainability aspects of a farm. The questionnaire was structured to adapt to each farmer's practical approach, thus organized into topics such as plant production, soil management, plant protection, water management, animal husbandry, biodiversity management, marketing, employees, energy and waste management, local economy, risk management, investments on the farm, etc.

Questions were linked to typical indicators which have various forms in SMART: some are based on yes-no questions, some are answered on a 0-100% scale, some have fixed answers to choose from, and in other cases, numerical values are to be stated (e.g. the amount of fertilizers used). The questionnaire was completed on the user interface of SMART Version 4.0, partly based on the interview with the farmer and partly based on observations gathered during the tour of the farm. Data was registered during the farm visit, notes were added in the questionnaire comment field at each question if needed, and then data was cleared and checked at a later time, but within a maximum of two days, while memories were still fresh.

To sum it up, sustainability assessment tools seem useful instruments to give structure to the dialogue between a researcher or advisor and the farmer. The reports and visual representations of an assessment may help show strengths and weaknesses. The potential for improvements should be identifiable and some formalized feedback be given to the farmer. The farmer in turn may wish to use the assessment results for marketing purposes, such as communicating the detailed benefits of his farming activities and his produce to the consumer.

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We are grateful to the numerous farmers and farm managers who willingly shared experiences about their farming and generously gave us the relevant information, including several hours of their precious time, often with exchange of a smile and a handshake. With this publication we hope to do additional justice to their efforts.

We also thank CAWR, the Centre for Agroecology, Water and Resilience from Coventry University UK for their financial support, which has allowed research into PC for nearly four years. This had been pivotal to get such a novel research field off the ground. The farm selections by agronomist Marion Buley at German organic wholesaler, Lehmann natur GmbH, as well as the financial support from the 'r e a l GmbH' retailer chain – the latter at the time still belonging to the Metro Group – added the necessary drive to jointly develop 'commercial PC fields of actions'. We are also extremely grateful to Sabine Zikeli and Marion Buley who gave very valuable critical comments during the editing process of this chapter.

This chapter is finally dedicated in memory of Prof. Dr. Sabine Gruber († 21 June 2021) for her contribution. She had supported the establishment of an annual lecture on PC in Agricultural Sciences at Hohenheim University, Germany and thus fostered dissemination of knowledge in the field. She departed far too early.

List of Abbreviations

1-11	–	One-Eleven concept
AAP	–	Average Annual Precipitation
AAT	–	Average Annual Temperature
A-B-CERT	–	Accreditation, Confirmation, Conformity Control and Certification Body (Organic Certification label, Italy)
AE	–	Agroecology
AMF	–	Arbuscular Mycorrhizal Fungi
AMSL	–	Above Mean Sea Level
BFOP	–	Bavarian Fruit Orchard Pact
CSA	–	Community Supported Agriculture
CT	–	Conventional Tillage
DHA	–	Dehydrogenase Activity
FAO	–	Food and Agriculture Organization
FiBL	–	Swiss Organic Research Institute; *Forschungsinstitut für den Biologischen Landbau*
FST	–	Farming Systems Trial
GM	–	Genetically Modified
HYV	–	High Yielding Varieties
ICEA	–	*Instituto per la Certificazione Etica ed Ambientale*, Italian Organic Certification Body
IPM	–	Integrated Pest Management
IR	–	Inhibition Rate
LM	–	Living Mulch
MP	–	Mountain Pasture
nbP	–	Nature-based Preparations
OA	–	Organic Agriculture
PA	–	Permaculture Action
PC	–	Permaculture
RCT	–	Ridge Cultivation Technique
RT	–	Reduced Tillage
RTD	–	Reduced Tillage (in combination with green manure)
SAFA	–	Sustainability Assessment of Food and Agriculture Systems
SMART	–	Sustainability Monitoring and Assessment RouTine
SOC	–	Soil Organic Content
SOM	–	Soil Organic Matter
UN	–	United Nations

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