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Permaculture Design in Agriculture: A Review

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Abstract

Permaculture is similar to agroecology and agroforestry with an emphasis on diversity and versatility to reduce the risk and exploit collaboration between systems and reduce labor and external inputs. Diversification of production has many potential benefits for farmers as a strategy (insurance) against risks. Permaculture is a small, autonomous horticultural design with minimal interference with the natural ecosystem. Permaculture is a combination of trees, animals, mixed crops, and diverse landscapes. All these movements are without the use of pesticides and in favor of the food cycle. Like organic farming, permaculture pays great attention to soil fertility.

Keywords: Diversification; Food Cycle; Autonomous Horticultural

Abbreviation: PIRN: Permaculture International Research Network

Introduction

The term permaculture has its origins in permanent agriculture and originates in Australia, where Mollison Bill, a professor and researcher at the University of Tasmania, and his student David Holmgren developed theories and practices [1]. They observed that intensive monoculture reduced the number of plants and animals around the area and those indigenous varieties disappeared [1]. By combining many disciplines, they wanted to facilitate change in agriculture to achieve a truly sustainable approach without reducing soil fertility or ecosystems [1]. These guidelines were established in 1972, and Mollison received the Right Livelihood Award in 1981, often referred to as the Nobel Prize, for designing low-energy, high-performance systems [1]. In [2] Bill Mollison published a comprehensive guide to Permaculture [2]. Permaculture, as defined by Mollison in [2], is the conscious design and conservation of agricultural production ecosystems that have the diversity, stability, and resilience of natural ecosystems [1]. Permaculture as defined by Holmgren in [3], thoughtfully designed landscapes that mimic patterns and relationships in nature, while providing food, fiber, and energy for local needs [1]. Permaculture is a method that considers many things, such as farm animals, renewable energy, economics, social life, natural water treatment, the food cycle, etc. [1]. Permaculture is a system similar to nature and based on the natural cycle and ecosystem [4]. Permaculture is a set of techniques and principles for designing sustainable human habitat, although Permaculture specialists design with plants, animals, buildings, and organizations [5].

From the above definitions, it can be understood that permaculture design has evolved beyond food production systems, which also includes the broader perspective of architecture and human relations. As an expert report in horticultural sciences, how to design a sustainable plant production system. The focus is on how to create a permaculture plan based on landowner goals, including selecting plants and combining the right crop for each farm [1]. Permaculture uses a variety of cultivation techniques, based on traditional methods combined with new research results to optimize productivity in the land, water, nutrients,

sunlight, and working hours [1]. There is a lot of emphasis on trees, shrubs, and perennials, but in some systems, there is a natural habitat for perennials [1] Figure 1.

Figure 1: Examples of production and education in the permaculture movement. Small farm with intercropped and perennials, worked partially with hand labor [6].

Joel Glanzberg, designer and environmental reconstruction expert, emphasized that Permaculture is a comprehensive design approach to all human needs [7] Figure 2.

Figure 2: Designing a permaculture site at USU following observation of the biological and social patterns interacting with the site [8].

Permaculture is one of the movements that have attracted people's attention but little systematic measurement has been done on it. Permaculture is an international network with comprehensive sustainability goals and focuses on a diverse production landscape [9]. The permaculture International Research Network (PIRN) was established in the UK in 2015 with more than 400 members and more than 40 countries involved [10]. Food security is also a complex issue and permaculture is a creative solution to this problem [11]. That food security does not mean producing more food, people must work together to take care of each other and the land [11]. The concept of food security in permaculture means food sovereignty, which is commonly known as the ability of individuals to provide food for their families in private [11]. But in 1996, La via Campesina introduced the concept of food sovereignty as the right of people to access suitable and healthy food produced through a healthy and sustainable environment [11].

The 12 Principles of Permaculture are as Follows

Observation and Interact

In designing permaculture, different types, times of day, and different types of cultivation should be considered. Ways to work and design with patterns found in nature must be considered [12].

Catch and Store Energy

Ways to re-accept the absorption and use of energy should be a priority. Energy should not be wasted [12].

Obtain a Yield

Agricultural yield production is necessary for independence. Performance is encouraging and they create positive opening loops [12].

Apply Self-Regulation and Accept Feedback

By better understanding how positive and negative work feedback in nature, systems can adjust themselves, thus changing the work involved in repetitive and rough overall management [12].

Use and Value of Renewable Resources and Services (Renewable Resources and Services)

We live in the world as a result of survival. Using renewable resources, using them at the right level, can help us limit the consumer [12].

Produce no Waste

Find a way to build scrap as a useful input to the system. Recycling, composting and waste reduction are generally increasingly important as production increases [12].

Design from Patterns to Details

We can see patterns in nature and society. This can be the backbone of our designs. Mindfulness is a way to address and solve many of our problems in resources [12]. This principle is known as an imitation of the natural ecosystem [13].

Main patterns or models that can be used for agricultural ecosystems such as grasslands such as savannas, rainforests or tropics. Where natural grasslands grow is not climatically suitable for tree planting, the natural pattern found here is the grasslands through which large herds of animals pass [13]. The strategy found here is to use grasses on natural plants and harvest them to feed animals for meat or milk [13].

Integrate Rather than Segregate

This requires the identification of complex relationships in nature and their useful use in interactions [12]. Biological interactions should be used to increase the productivity and stability of the agricultural system [13]. Element integration makes it possible to use multi-purpose elements such as chickens for pest control in the Integrate system for orchards. Integration also allows for system stability through multiple elements, such as chickens and fruit trees, both increasing food production performance [13]. Also, the dual use of cereals and canola is done for forage in the vegetative stage and then for the seeds, this improves the properties of the soil and also increases livestock and crops [13].

Use Small and Slow Solutions

Smaller systems are easier to maintain than larger systems, use local resources better, and also produce more sustainably [12]. This principle originates from a fundamental pattern in living things called cellular design [13]. The relationship between farm size and land productivity has been investigated. An inverse yield relationship indicates that smaller farms are more productive [13].

Use and Value Diversity

Diversity enhances flexibility. A single-ship community is vulnerable to unexpected change. Permaculture seeks to understand the past, present, biological potential, and diversity of ships [12]. Diversity is one of the foundations of ecosystem adaptation and stability [13]. For example, increasing pollen diversity for plants that are dependent on pollination has a positive effect [13]. Ecosystem diversity also has a positive effect on pest control [13].

Use Edges and Value the Marginal

Instead of ignoring the margins, we should look for ways to use their diversity and productivity [12]. For example, where a forest collides with a meadow, this shade promotes the growth of some plants that grow neither in the shade nor in the sun.

Creatively Use and Respond to Change

We can make a positive impact on the inevitable changes, watch carefully and then intervene at the right time [12]. Earth's ecosystem is complex, meaning that its response to human use is unpredictable or uncontrollable. To use creatively and respond to these changes, systems need to be monitored and evaluated [14]. Holmgren [3] explains that living systems change inherently; they grow, mature, and eventually die. System designers should try not to prevent this change but to intervene at the right time and make a positive change (Figure 3).

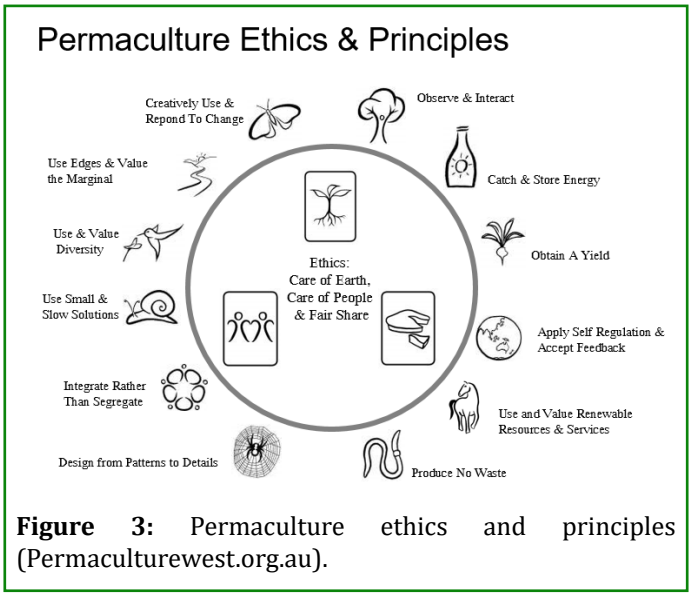

Figure 3: Permaculture ethics and principles (Permaculturewest.org.au).

Permaculture in Practice

Harvest Rainwater

An initial start to rainwater harvesting is to build or purchase a water supply system, such as a barrel connected to a home [1].

Design a Plant Guild

The plant board outlines the design concepts of forest ecosystems. Start with a layer of the canopy, such as large fruit trees or nuts. Below this layer dwarf fruit trees grow. Around and under the tree, shrubs grow like berries. Then surround the plants with vegetables and complete the whole system with cover plants and the topsoil with plants like strawberries. You can also cover the vertical layers with grapes or cucumbers [8].

Intercropping

Pollinators, natural enemies, earthworms, and soil microorganisms are all key components of food cycle regulation, natural decomposition, and pest control. The type and frequency of diversity in different agricultural systems depend on age, structure, and management [1]. Intercropping

or polyculture is common in tropical agriculture but is rarely found in modern agriculture in the Western world [1]. Experiments have shown that intercropping can result in greater yields than crop cultivation alone if crop selection is appropriate for the local ecosystem [1].

Benefits of Mixed Cultivation

Pest Protection using Biodiversity

A review of published studies found that 52% of all herbivorous species were less common in polycultures than in monocultures. Biodiversity should be aimed at maximizing ecosystem processes and structural complexity, rather than increasing the number of species [1].

Water Use

Mixed cultivation with trees may increase the soil moisture ratio because more canopies reduce soil evaporation [1].

Crop Yield

When resources are limited, the use of intercropping relative to single crop increases yield [1].

Production

Combining products with a variety of production time cycles can lead to the continuous production of food products for humans and animals throughout the year [1].

Food Accumulation

Measurement of higher content of organic matter, nitrogen, potassium, phosphorus and calcium in the tree canopy compared to the surrounding soil [1].

Effect on Climate

The most important combination effect of woody and non-woody species is the change in microclimate, which in turn affects the growth of all system components. A tree can transpiration 450 liters per day, so it consumes 100 MJ of heat energy, which plants can reduce temperature and increase humidity [1].

Companion Planting

Companion planting next to another plant is due to pest control, pollination, maximizing space utilization, and increasing crop productivity. Positive allelopathy may be one of the mechanisms by which implantation works. Another of these is attracting beneficial insects to the garden. But many plants are suitable for each other due to their shape, such as slender and tall plants such as Allium sativum, with short and wide plants such as Lactuca sativa. Plant shape, shade tolerance, etc. are all factors that make plants work together instead of competing [1]. Mobile planting is a great way to reduce your external inputs. This means the range that each plant can provide and what the plant needs to grow. The same can be done for several plants and that one plant can provide other nutrients when planted together [1]. An example of planting plants is the use of corn, beans, and squash. Corn provides a natural backbone for beans, beans provide nitrogen for other plants planted in the soil, and squash as a natural cover reduces weeds, retains soil moisture, and acts as natural soil mulch. Slow and coarse hair spines act as a deterrent. As a result, more over yielding is seen from the combination of three crops growing together on the same land than when each crop was planted alone. Three products are also dietary supplements. Beans are rich in protein, corn provides carbohydrates, and the squash provides vitamins [1] Figure 4.

Figure 4: A Three Sisters Garden at the UMass Amherst Campus, Massachussetts-part of the University's Permaculture Initiative (www.UMassPermaculture.com).

Perennials: Trees, Shrubs, and Grasses

Perennials encourage planning and investment because relatively stable performance can be expected without extra work. Annual leaf fall and fine root decomposition deliver the significant organic matter to the soil [1]. Symphytum officinale and S. x uplandicum are claimed to have higher potassium levels than most plants, so it is used as direct mulch for plant compost and in plant extracts [1]. The multi-branched system provides wildlife cover, adds organic matter to the soil, and reduces wind speed [1].

Annuals

Most vegetables are annuals and should be planted every year [1].

Annual Self-Seeders

Some plants easily sow and germinate if there is suitable soil

near them [1].

Climbers

Climbers can be trained on fruit trees and become an attractive place. As a result, the growing space becomes more efficient and the harvest is doubled, which saves labor and builds up support and guardianship. This technique is used in tropical areas where light intensity is high, where light is sufficient to reach the canopy of the tree as well as the climbing plant [1].

Plant Competition

Interspecific competition between species is different from the intraspecific competition. Multi-species plants may have different demands on existing resources [1]. Competition may be fierce between species with similar morphology. When resources are not limited, the single-ship system usually has the most efficient system for receiving resources [1]. Due to the fact that trees use more soil volume, the effect of nutrient competition for the crop is more intense [1]. C3 plants (most dicotyledons) are more efficient at absorbing CO2 at low radiation levels than C4 plants. Different growth of C3 and C4 products allows combining products with different radiation requirements. Due to different growth strategies, both products are affected by little competition [1].

Allelopathy

Some plants reduce the strength of other plants, plants are highly sensitive to allelopathic chemicals, so choosing the right neighbor plants can prevent negative effects [1]. Allelochemicals can be produced in various forms, such as root secretions, chemicals that are leached from plant leaves into the soil, decomposition of dead plants, and chemical volatiles that are released into the atmosphere [1]. Plants that have a negative allelopathic effect include Mentha spp., Thymus spp., and Salvia spp., *Foeniculum vulgare*, *Angelica archangelica* and *Levisticum officinale* and the Tagetes spp., Chamaemelum nobile [1]. *Juglans regia*, *Sambucus nigra*, and *Salvia officinalis* are also examples of forest plants that have negative allelopathic effects on other species [1].

Planting Patterns and Techniques

It is very important to find a planting pattern that is suitable for the area and the environmental conditions. Several techniques can be used to maximize harvesting. Rows should be designed to prevent erosion. Where the ground is flat, placing the row in an east-west direction reduces shadows [1]. Field experiments in Sweden have shown that 800 m^2 of land is needed to feed a vegetarian during the year [1].

Designing a Forest Garden

In every garden, there are varieties of long-lived and short-lived plants, as well as products that mature sooner or later, which means that there is a mixture of products in the garden [1]. This means changes in the indoor climate that affect crop growth [1].

There are three main ways to develop a forest garden that should be evaluated by the community:

Planting all the layers at once (Planting all the layers at once): This method is the closest substitute of nature in which the light gradually reaches the plants, trees, and plants resistant to shade but the growth of plants is slow. In the first year, the harvest will be for herbaceous annuals. In the second year, most perennial vegetables are harvested and some fruit trees begin to bear fruit. As the trees get bigger and the shade increases, the performance of the lower layers decreases. The demand for light in vegetables and shrubs may push them to the edges [1].

Planting in stages: Only trees are planted in the first year, shrubs and vegetables are planted a few years later [1].

Planting underneath existing fruit trees: The forest garden changes with the death of old trees and the removal of branches, which allows light to enter for the growth of shrubs and vegetables. Dead trees may be used as scaffolding for climbers. Elsewhere in the garden, the amount of shade may increase with the growth of trees, a disadvantage of this method is that perennial weeds grow along with the roots of trees [1].

Alley Cropping/Hedgerow Intercropping

Alley cropping involves the growth of food crops between rows of hedged shrubs and planted shrubs, preferably leguminous species. This method reduces food leaching, acts as a windbreaker, controls weeds, and controls erosion on sloping lands [1]. The use of windbreaks, as with evergreens, deciduous trees, or shrubs, controls wind erosion and also reduces wind speeds, which are beneficial to agriculture and create habitat for wildlife [1]. During crop growth, the margins are pruned to prevent shading in the crop as well as to provide biomass. The addition of nutrient-rich mulch has a favorable effect on the physical and chemical properties of the soil and increases crop productivity [1].

Raised beds: By collecting soil in the wall structure, the beds can rise 30-100 cm above the ground to facilitate the work. The advantage is that the soil warms up quickly in the spring, but the disadvantage is that in the summer the soil is fast. Drying may require irrigation. Complete compost may be used as a long bed [1] (Figure 5).

Figure 5: Raised bed made with the compost. Maria Martina Schmitt, Graphik Design, Wien.

Edge cropping: At the edge of a forest, the farm provides a micro-climate for different species that have different light needs, access to water, and so on. This creates great potential in the design of planting media, in polyculture cultivation according to the needs of each species [1].

Keyhole beds: The Keyhole beds pattern allows access to and diversification in small habitats. The maximum width of the beds should not be more than 170 cm to facilitate weeding and harvesting. Placing stepping stones in the middle of the bed facilitates access to plants [1] (Figure 6).

Figure 6: The keyhole beds with paths and stepping stones, Javier Palacios.

Herbal spiral: Spiral plants are compact vertical gardens that allow you to manage wind and water flow. Solids such as stone or brick have been used to make the spiral frame. Stone or brick walls retain heat, insulating the roots from the cold. Remember that in the Northern Hemisphere, water moves clockwise so be sure to make a spiral in the direction of the natural flow of water [8] (Figure 7). When creating a culinary herb garden, designing and building a tall spiral for efficient land use is very practical and beautiful, this should be planted close to the kitchen to facilitate harvesting [1]. Mollison suggests a base 200 cm wide with a height of 100-130 cm [1]. On the sunny side, it suggests a combination of Thymus spp, Rosmarinus officinalis and Salvia officinalis [1]. On the shade side Mentha spp suggests Petroselenium crispum, Allium schoenoprasum and Coriandrum sativum. Of course, the choice of plant depends on the opinion of the consumer [1] (Figure 7).

Figure 7: University of Massachussetts' campus permaculture garden also features an herb spiral. This serves as a space organizer, visual attraction, and walkway for the campus garden-stacking functions! [8].

Swales: Swales is a shallow canal with two sides of a gentle slope. This technique is used to prevent runoff and increase soil water retention. It is therefore widely used in arid and semi-humid areas on steep slopes and flatlands in urban and rural areas [1]. Long pits with a width that depends on the available space. The bottom of the pit is filled with pine bark, sawdust, and sand [1] Figure 7 below. The soil is saturated with water and is available to the plant for a long time [1]. Trees are a key component of the swale planting system because they use large amounts of water and help prevent erosion [1] (Figure 8).

Figure 8: Garden basins/swales form a living sponge of mulch and vegetation. Basins are designed to infiltrate water quickly so there are no problems with mosquitoes or anaerobic soils. These basins, with their spongy mulch and soil-burrowing plant roots, infiltrate all water within 20 minutes (© Rainwater Harvesting for Drylands and Beyond; www.harvestingrainwater.com).

Figure 9: A swale where water is retained and used efficiently by the crop, Andrew Jeeves.

Suntraps: Suntraps is a place that is protected from the wind and is suitable for receiving sunlight. By planting a U-shaped plant fence at the edge of the west-north-east field, a warmer environment is obtained [1] (Figure 10).

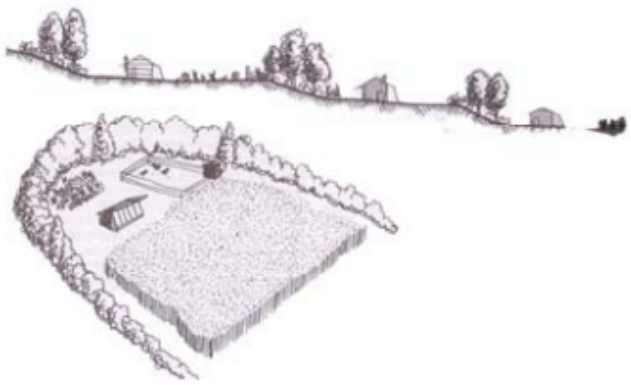

Figure 10: The bushes slow down the cooling winds and a warmer microclimate is created, Andrew Jeeves.

Evergreen, perennial hedges have been selected as shelters from strong winds without blocking sunlight. Evergreen species such as Mahonia aquifolium and Mahonia japonica are sheltered for insects, produce edible fruits, and nest for insectivorous birds [1].

Riparian forest buffer: Farm management alone is not sufficient to significantly reduce nutrient leaching from adjacent lands to adjacent catchments [1]. The coastal forest retainer is a three-zone system that includes a wooden non-residential area adjacent to the pond and then an area of trees with a margin of herbaceous plants around the farm [1]. The shade produced by trees lowers the water temperature in summer, which can improve habitat for aquatic organisms [1]. The buffer zone stabilizes the coastal flow, reduces flood damage, and also creates recreational opportunities [1].

Some Effects of Permaculture

Noise reduction effect: The wind moves through the leaves of the trees and suppresses part of the annoying sounds, which is the phenomenon of masking. Leaf layers, especially thin and dense ones, react by moving to sound waves. Research shows that leaves reduce noise by about 5 decibels [15].

Air-purifying effect: Research has shown that trees reduce dust particles by up to 2.3 due to leaf surfaces. It also absorbs dangerous gases. Also, each square meter of leaves produces about 4 liters of oxygen during 12 hours of daylight. A human consumes 175 kg of oxygen per year, which is about 335 liters per day [15].

Building temperature balance effect: Green facades and ceilings act as thermal insulation and have a pronounced cooling effect, as well as thermal insulation in winter. Residents of green areas are more active and use less water [15].

How to Create a Permaculture Plan

The 6 steps to creating a Permaculture scheme are as follows [1]:

- Identification of planning problems, opportunities, and goals.
- Landscape analysis on a regional and local level.
- Detailed studies.
- Planning area concepts, options, and choices.
- Plan and design implementation.
- Revaluation.

Identifying problems, planning, opportunities, and goals: Objectives must be identified and provide the basis for the planning process. Social, economic, political, and environmental problems and opportunities must be identified because the goals provide an ideal situation for the future [1].

Landscape analysis at the regional and local level: This step includes a list of specific areas, locations, and sites. The main purpose of the local analysis is to gain insights into natural processes and human programs and activities. This information includes geology, climate, soil properties, vegetation, and wildlife. The production of allopathic compounds by plants must be considered. We should also look for information about plant growth patterns [1].

Detailed studies: The purpose of a careful study is to gain an understanding of the relationship between human values,

environmental opportunities, and constraints. Computer applications (GIS) are used for large and complex projects. Design with the observed parameters to select the most suitable product combinations. Topographic maps are often available on the Internet and can be used as a basic map for making plans [1].

Areas and Sections

The design area is divided into 5 sections and the area for practical reasons [1].

A House Where Some Potted Plants and Vines May Grow

Zone 1: Near the house are plants that need maintenance such as frequent watering, fertilizing, pruning and harvesting, continuous protection from pests, and so on. These plants are mostly annuals, kitchen plants, and medicinal plants. Seedlings, young trees are to be located in the outdoor area and water collection area, preferably located in this area.

Zone 2: Annual crops that have a limited harvest season and a long growing season are grown with perennials. Fruit trees that are used for their consumption, have a limited harvest season and need pruning and fertilization can be planted in this area.

Zone 3: Plants produced in larger quantities are suitable as a staple food or for commercialization for cultivation in this area.

Zone 4: Resistant trees that require less maintenance, such as trees used for timber, are planted farther away from home. On the edge of the earth, where wildlife is destroyed, deadwood is collected for fire. Irrigation dams may be constructed to direct water into the area.

Zone 5: This natural place is an unmanaged environment used for fun and learning the laws of nature.

Concepts of area Planning, Options and Choices

This includes developing concepts for area planning. Concepts are based on a combination of the information collected and step-by-step analysis. A list of products is made and a microclimate is mapped for each farm. Land size is a major factor that can be considered for how it is designed [1].

Program Implementation and Design

This step is about how to design using the information in the previous steps. This stage includes land acquisition and a strategy for implementing the plan [1].

Evaluation

It is important to evaluate the design after its implementation. The design of a system is evolving, it can never be completely completed [1].

Two Examples of Land Plans

Land 1: The farm below, the farm is located on a low slope and the orientation of the beds is preferably north-south. Access to water without storing it is acceptable. There is easy access to light and nitrogen, which is suitable for perennials such as Helianthus tuberosus with Cucurbita pepo (Table 1, Figure 11) [1].

Number	Latin	English
1	Cucurbita Pepo	Pumpkin
2	Helianthus Tuberosus	Jerusalem Artichoke

Table 1: Plants to be introduced to field.

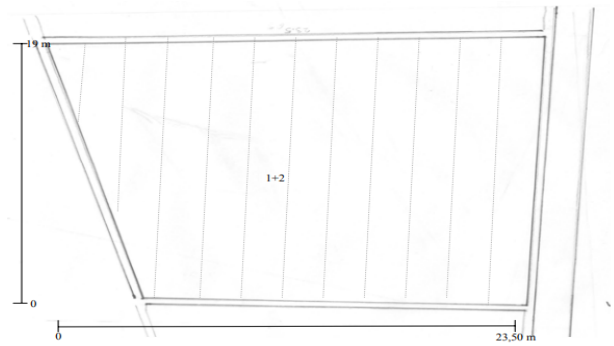

Figure 11: Showing the composition and design of plantation in field 5.

Land 2: This land is one of the driest lands on the hillside with a road behind the eastern stone wall, with pits that divert rainwater. The slope of the ground causes the beds to be in the north-south direction, which is to prevent the passage of water and erosion. The proposed plants for the design of this farm are listed in the table below. The medicinal tree Ginkgo biloba grows in drylands, where it is planted in the eastern part of the gate near the road, where its shade does not interfere with crops, this product produces delicious seeds with high nutritional value and medicinal leaves [1]. *Laurus nobilis* is a tree planted with the fruit shrub of Feijoa sellowiana. *Asparagus officinalis* also grows well in this field, which is also useful by adding gypsum to increase the pH. A perennial product needs little attention but has a high price in the market. Sunflower (Helianthus annuus) is also recommended to be planted in a large part of the field, which is popular with humans and animals [1]. Pastinaca sativa is planted with *Foeniculum vulgare*, they belong to the Apiaceae

family, which are suitable for attracting pollinators [1]. *A. officinale* and *H. annus* were planted in areas that did not shade other plants [1]. *Hypochoeris radicata* is a medicinal plant that is recommended for planting in the southern part [1] Table 2, Figure 12.

Number	Latin	English
1	Asparagus Officials	Asparagus
2	Feijoa Sellowiana	Pineapple Guava
3	Foeniculum Vulgara	Fennel
4	Ginkgo Biloba	Maiden Hair Tree
5	Helianthus Annuus	Sunflower
6	Hypohcoeris Radicata	Cat's Ear
7	Laurus Nobilis	Sweet Bay
8	Pastinaca Sativa	Parsnip

Table 2: Plants to be introduced to field.

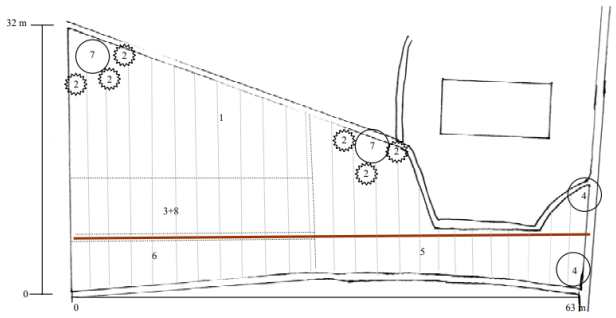

Figure 12: An illustration of the composition and design in field 3.

Conclusion

Permaculture is more than just food production, it can be used for organizations, homes, and landscapes. There are three roots of Permaculture: land care (care of natural land systems and land healing), care of people (care of basic needs of people such as food, water, shelter, work, and friendly human relations), and also a range for growth (consumption). To the extent possible and to give additional resources to the people [16]. To care for the land, the people, and identify growth constraints, we must understand the need for regeneration. Food and landscape regeneration is an essential standard for environmental sustainability and functional permaculture. Food-producing landscapes mimic the diversity and resilience of natural ecosystems. Permaculture is the conscious design and maintenance of agricultural production systems that have the diversity, stability, and resilience of natural ecosystems [17,18].

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