BIODIVERSITAS
Volume 22, Number 4, April 2021
Pages: 2032-2044

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d220452

The structure of permaculture landscapes in the Philippines

JABEZ JOSHUA M. FLORES[1,♥], INOCENCIO E. BUOT JR.[2,♥♥]
[1]School of Environmental Science and Management, University of the Philippines Los Banos. College, Laguna 4031, Philippines
♥email: jmflores4@up.edu.ph (corresponding author)
[2]Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Banos. College, Laguna 4031, Philippines
♥♥email: iebuot@up.edu.ph

Manuscript received: 17 March 2021. Revision accepted: 27 March 2021.

Abstract. *Flores JJM, Buot Jr. IE. 2021. The structure of permaculture landscapes in the Philippines. Biodiversitas 22: 2032-2044.* Biodiversity plays a crucial role in sustainable agriculture. Permaculture is a design philosophy that values this role as it consciously integrates diverse components into the farm landscape. The purpose of the study was to characterize the general structure of permaculture landscapes in the Philippines and identify the landscape components that comprise its farming systems. The research was conducted in 12 permaculture farms in 11 provinces in the Philippines in 2018. Aerial photography and farm inventory were employed for data collection. A crop diversity survey was conducted using a modified belt transect method with alternating 20 m^2 plots within a 1 ha sampling area. Full enumeration of plant species in each plot was performed to determine species richness and samples were manually counted to compute for the Shannon-Wiener Diversity Index. Results of the study showed that permaculture landscapes were organized into six spatial zones: 'house,' 'garden,' 'grazing,' 'cash crops,' 'food forest,' and 'wilderness.' It was identified that each zone contained components belonging to six categories: abiotic, biotic, man-made structural, technological, socio-economic, and cultural. 'Biotic' results showed that all sites recorded high species richness (>20-65) with the highest found in Glinoga Organic Farm with 65. Aloha House in Palawan had the highest diversity with a score of 0.311. An analysis of the ratio of plant species per plant category showed that the vegetable/cereal crops dominated the landscape in 50% of sites. While 20% were characterized by tree/fruit-bearing crops. Perennial species were the most abundant in all sites with 75-95% of the total plant species. In conclusion, permaculture provided a design framework for restructuring our agricultural landscapes into diverse and productive ecosystems for human settlement and food production.

Keywords: Agroecology, agroecosystems, biodiversity, diversified farming systems, ecological network, landscape ecology

INTRODUCTION

A fast-growing global population leading to increased demand for staple food crops has given way to massive agricultural practices of monoculture (Kremen et al. 2012). But the homogenization of landscapes has resulted in soil degradation (Borelli et al. 2020; Borelli et al. 2017), loss of biodiversity (Le Roux et al. 2019) and its natural habitats (Goncalves-Souza 2020), and tradeoffs in the delivery of ecosystem services (Power 2010; Hirschfeld and Van Acker 2021). However, agriculture has remained to be largely a plantation type of enhancing food security and hence, the survival of the human race. In the long run, however, this is undoubtedly counter-productive and unsustainable.

To address the disruptive effects of massive agricultural practices, permaculture, as an alternative, presents a major paradigm shift that aims to mimic the complexity and resilience of natural systems manifested in the design of agricultural landscape structures. Mollison (1988) described permaculture as 'a system of assembling conceptual, material, and strategic components in a pattern which functions to benefit life in all its forms'. This system, when applied to agriculture, creates complex, diverse, and multifunctional landscapes. However, such diverse landscapes share common features which seek to achieve household food security while being conscious of biodiversity.

Permaculture landscapes have been studied in various countries like Japan (Chakroun 2019), Malawi (Kamchacha 2013), and Malaysia (Ismail and Affendi 2015). Such landscapes were characterized by agroforestry systems, free-range grazing (Krebs and Bach 2018), swale systems (Ismail and Affendi 2015), greywater collection systems (Rivett et al. 2017), forest edges (Krebs and Bach 2018), food forest (Kelly-Bisson 2013), and edible gardens (Ismail and Affendi 2015).

In the Philippines, however, the few existing studies on permaculture have created a knowledge gap on the design and structural characteristics of permaculture landscapes which demonstrates how the system can actually contribute to household food security. To address this knowledge gap, the study aimed to characterize the structure of permaculture landscapes and identify landscape components in permaculture.

MATERIALS AND METHODS

Study area

Twelve (12) permaculture sites representing the three major island groups of the Philippines, i.e. Luzon (9), Visayas (2), and Mindanao (1) were selected for the study (Figure 1). Sites were sampled from a database of permaculture practitioners in the Philippines using maximum variation sampling (Cohen and Crabtree 2006). Climate type, land area, geographic location, as well as availability of the respondents, were the factors considered for selecting study sites. Three days were allocated for data collection at each site. Fieldwork was conducted from August 31 to November 6, 2018.

Characterization of landscape structure

Determination of zones and system boundaries. Respondents were requested to conduct a detailed farm tour to explain the general design and zoning plan of the site. Aerial photographs using DJI Spark and Ryze Tello drones were taken with permission to use as reference. Farm property boundaries were marked and geotagged using a Trimble TDC600 global positioning system (GPS) device. Upon review of aerial photos and GPS coordinates, zone plan and system boundaries were determined and plotted on Google Earth Pro.

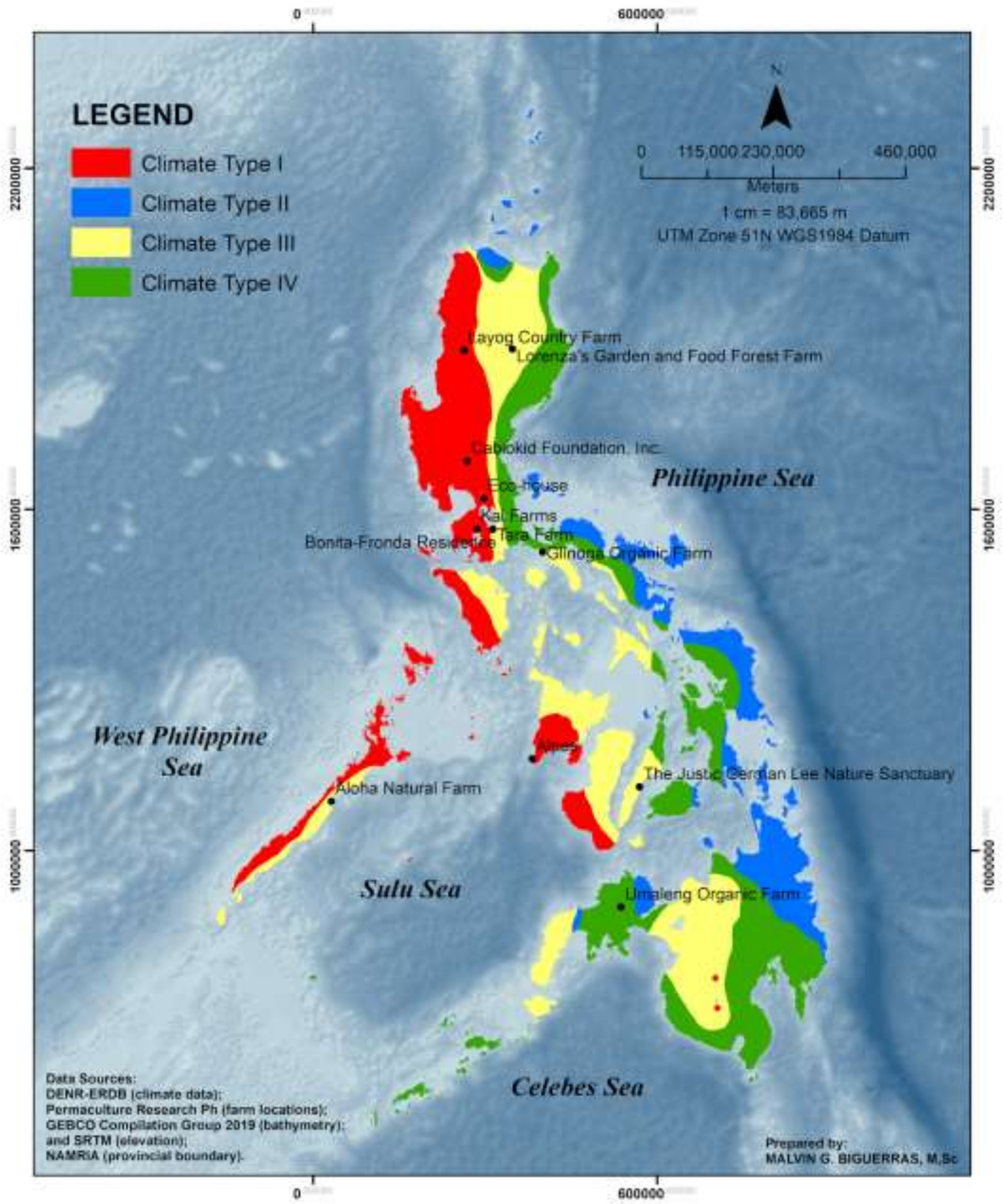

Figure 1. Study sites on a climate map of the Philippines Twelve permaculture sites were discovered in the study. Shown in the map are the locations overlaid on climate type data: 5 sites in Type 1, 6 sites in Type 3, and 1 in Type 4.

Identification of landscape components. To characterize the landscape structure, ground-truthing of landscape elements, or discrete objects (Antrop and Van Eetvelde 2017), was performed using direct observation and manual counting to create a farm inventory. Man-made landscape elements (i.e. built structures, machinery, and installations) and continuous landscape features, or components (Antrop and Van Eetvelde 2017), such as bodies of water and natural land formations were fully enumerated, geotagged, and recorded on a field datasheet. Both 'discrete objects' and 'continuous landscape features' are referred to as 'components' in the study.

For biotic components (flora and fauna), a modified belt transect method (Grant et al. 2004) was used in a 1-ha sampling grid (Figure 2). In this method, two intersecting 100-m transect lines labeled 'A-T' on the x-axis and '1-20' on the y-axis were set up using colored nylon ropes and 1-m long orange PVC pipes labeled with a corresponding alphanumeric code (i.e. Plot A-10) to indicate location on the grid. Alternating 20-m^2 plots were placed 5 m apart along the two transect lines for a total of 38 plots. Full enumeration of species on each plot was conducted to determine species richness and sample populations were counted in each plot to compute the Shannon-Wiener Diversity Index using the formula (Shannon and Weaver 1949; Wiener 1939; Wiener 1948; Wiener 1949):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Soil samples were also collected in the same plots for *in situ* colorimetric soil test analysis using a rapid soil test kit.

RESULTS AND DISCUSSION

Characterization of landscape structure

Design and function of permaculture zones. A brief overview of the twelve permaculture sites is shown in Table 1. Nine are located in Luzon in the provinces of Cavite, Isabela, Laguna (2 sites), Metro Manila, Mountain Province, Nueva Ecija, Palawan, and Quezon; two are located in Visayas in the provinces of Antique and Cebu; and one is located in Mindanao in the province of Zamboanga del Sur.

Figure 3 shows that the permaculture farms in the sites were designed into six zones (Babac 2018) which were named based on the most dominant or most common components. The zones are Zone 0 (House), Zone 1 (Garden), Zone 2 (Grazing), Zone 3 (Cash Crops), Zone 4 (Food Forest), and Zone 5 (Wilderness). Zone labels “0-5” are based on Mollison (1988). Each zone will be discussed here in terms of landscape layout and composition.

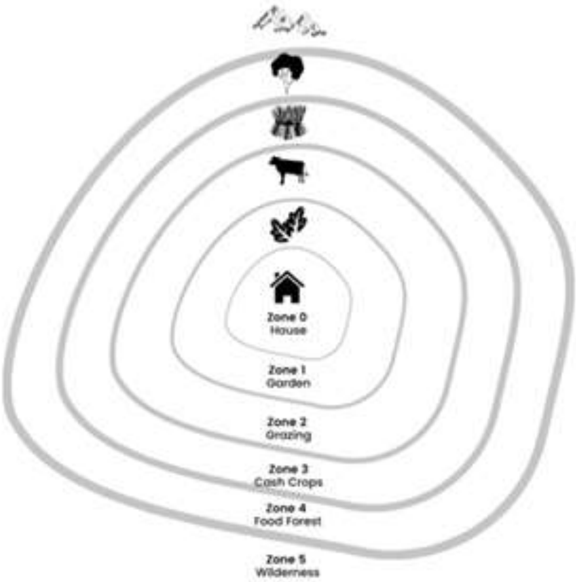

Figure 3. The permaculture landscape structure is characterized in this study by 6 zones: Zone 0 (house), Zone 1 (garden), Zone 2 (grazing), Zone 3 (cash crops), Zone 4 (food forest), and Zone 5 (wilderness).

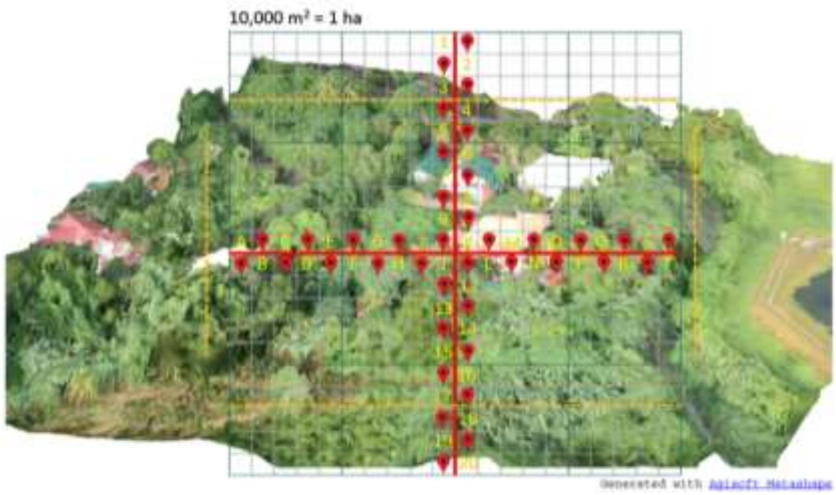

Figure 2. Sampling method for biotic components. A modified belt transect sampling method was used to identify the species richness and diversity of biotic landscape elements such as vegetable crops and livestock (3D model by Agisoft Photoscan, 2016).

Table 1. Overview of permaculture study sites showing location (province), land area, elevation profile, and description of the site's characteristics and main functions

Study site	Complete name	Land area (ha) & elevation profile (min-max m asl.)	Brief description of the permaculture site
Aloha House	Aloha House Inc., Palawan	0.28 ha 52-40 m asl.	A residential area and diversified organic urban farm based on an aquaponic system; features an orphanage, bed and breakfast services, and natural farming training services.
Alpas	Alpas Resort, Antique	0.75 ha 14-10 m asl.	A coastal private property with access to beachfront, accommodation facility and restaurant service that specializes in local cuisine while advocating the use of local products; features an herb and vegetable garden with fruit trees.
Cabiokid	Cabiokid Foundation Inc., Nueva Ecija	9.77 ha 14-10 m asl.	A diversified organic farm featuring rainwater catchment ponds for aquaculture and dry season irrigation; farm is buffered by thick forest edges that function as wildlife corridor and habitat.
Eco-house	Eco-house - The Philippine Permaculture Association office, Metro Manila	0.033 ha 52-40 m asl.	A residential home made of clay-cement mixture; features a rainwater harvesting system, solar power system, and home garden with small fish pond. Office of the Philippine Permaculture Association.
Glinoga	Glinoga Organic Farm, Quezon	20.50 ha 21-14 m asl.	A diversified organic farm located within a mangrove ecosystem and rice-coconut agroecosystem; focuses on hyperlocal food production and value-added products using natural farming techniques.
Jubileeville	Bonita-Foronda Residence, Laguna	0.35 ha 24-20 m asl.	A residential home with perennial tree crops and backyard garden irrigated by a swale system and a manmade rainwater catchment pond.
Kai Farms	Kai Farms, Cavite	8.68 ha 464-422 m asl.	An organic farm featuring multi-cropped vegetables, herbs, and fruit trees; uses plant-based compost and plant-based, zero-waste packaging materials; advocates seed-saving.
Lorenza's	Lorenza's Garden and Food Forest Farm, Isabela	1.00 ha 128-124 m asl.	An isolated do-it-yourself homestead property (under construction) with a vegetable and herb garden buffered by native trees around the perimeter.
Nature Sanctuary	The Justice German Lee Jr. Nature Sanctuary, Cebu	3.73 ha 11-0 m asl.	Mangrove and coastal forest ecosystems featuring a complex system of meandering swales; features bamboo structures, compost toilet system, and a variety of appropriate technologies.
Olaussen	Olaussen Permaculture Park in Layog Country Farm, Mountain Province	0.54 ha 912-864 m asl.	A diversified upland organic farm located on an ancestral property with indigenous Igorot origins called Layog Country Farm; emphasizes foraging and preservation of indigenous culture through food and farming
Tara Farms	Tara Farms, Laguna	1.00 ha 22-18 m asl.	A residential farm-resort setup with rice production, organic herbs and vegetables, and free-range native pigs.
UmaLeng	UmaLeng Organic Farm, Zamboanga del Sur	2.16 ha 52-50 m asl.	A rice-duck integrated farming system with aquaculture, organic herb and vegetable pocket gardens, fruit orchard, and organic soap production facility.

Zone 0. The 'house' is the section of the permaculture landscape where the main place of residence is located. This area features shelters built from renewable materials (Van der Lugt 2006) such as *Bambusoideae* sp. (bamboo) in Nature Sanctuary and UmaLeng, *Corypha elata* (buri palm) and *Saribus rotondifolius* (anahaw) in Glinoga. Other houses were traditionally constructed with concrete and lumber. Zone 0 was observed to be the center of human activities and was the most frequented area by people according to interviews and direct observations. Some of the activities observed here include cooking and dining, sleeping and resting, vegetable packing, receiving guests and social activities. Food processing either for personal use or for selling was also observed to be conducted in this area. As the most frequently used zone, the design of the main house was a priority of all practitioners in their permaculture strategy before expanding into the management of outer zones. Since all sites are privately owned, selecting the location of Zone 0 suggests that permaculture practitioners have control in the design of the farm landscape.

Comparing our findings with other countries we can see that these Zone 0 design features are not unique to the Philippines setting. Similar designs were also documented in permaculture sites in Indonesia (Putro and Miyaura 2020). As for the components, assemblies of green innovations, do-it-yourself systems, and appropriate technologies are very common features in permaculture houses around the world. Greywater treatment systems and composters, were documented in communal ecovillages in Brazil (Abdala and Mocellin 2010) and in middle-income households in Turkey (Abiral 2019). In Vietnam, human excreta fertilizer from compost toilets is a common practice (Jensen et al. 2008.)

Zone 1. The 'garden' zone contains crops for household consumption and plants for aesthetic purposes (Sofo and Sofo 2020). It is located right next to Zone 0. As shown in Figure 4, it is characterized by a mixed cropping system (Theunissen 1994). The zone's primary function is to provide accessible fresh food to the household, particularly edible herbs (i.e. *Origanum vulgare*, *Ocimum basilicum*) and vegetable crops (i.e. *Solanum melongena*, *Abelmoschus esculentus*) for daily consumption and subsistence (Putro & Miyaura 2020). Ornamental and flowering (i.e. *Cosmos bipinnatus*, *Sansevieria trifasciata*) plants provide aesthetic function in this area (Khachatryan et al. 2020). Activities observed were seed sorting and sowing, compost-making, potting and transplanting, watering of plants, and mulching of garden beds with dried grass and leaves. Vegetable gardens such as these are also common components in households in South Africa and Zimbabwe (Didarali & Gambiza 2019) as well as Japan (Chakroun 2019). According to Putro and Miyauro (2020) permaculture home gardens in Indonesia (Putro and Miyaura 2020) are based on the traditional *pekarangan* system (Kaswanto and Nakagoshi 2014).

Zone 2. The 'grazing' zone is an area for livestock grazing (Kariuki et al. 2021), farm animals, and aquaculture. It is located further away from the house and is usually a large open space. This area was observed to have a mixture of various grass species and forage crops for animals. The zone is mainly used for free-range grazing of livestock (goat, pigs, carabaos) such as in Glinoga and Tara Farms. And for sites that have ponds like Aloha House and Cabiokid, aquaculture is also practiced here. Since the animals forage on their own, minimal human activity and supervision were observed in this zone. In some sites, surplus vegetables from garden zones are fed to animals which are common in crop-livestock landscapes. Research has shown that crop-livestock systems are common in small-scale farms in Asia and are beneficial for ecosystem health and rural livelihoods (Paris 2002; Devendra and Thomas 2002).

Zone 3. This is the 'cash crop' zone which interfaces with the grazing area and food forest zones (Figure 5). A larger area compared to the previous zones, this zone is mainly characterized by crops for commercial use but sometimes merges with Zone 2 during fallow period according to interviews. Majority of human activities performed in this zone occurs only during planting season and harvest time. Most cash crop zones documented were rice fields thus component composition changes every season. Similar to Zone 2, growing cash crops such as grains are prone to monoculture management for cost-effective harvesting in order to maximize production (Gabriel et al. 2013). In most countries, agricultural landscapes are mostly characterized and dominated by single-crop plantations such as wheat and corn (USDA 2019), oil palm *(Elaeis guineensis)* in Indonesia (Rist et al. 2010), while rice fields cover 48 million hectares of land in Southeast Asia alone in 2010 (FAOSTAT 2012). On the agricultural landscape matrix, patches of other plant species are rarely seen.

Zone 4. The 'food forest' zone is located in the furthest area of the farm. Photographic evidence showed that this zone is dominated by trees as it provides a buffer zone from the surrounding environment. This is most evident in Cabiokid, Lorenza's, and Nature Sanctuary (Figure 6). The food forest is characterized by an agroforestry system of production wherein perennial crop species are grown for fruits, timber, and fuelwood. Similarly, fruit tree agroforestry systems in Vietnam (Do et al. 2020) have reported having the same characteristics while yielding higher profits compared to single-crop systems. The food forests observed were primarily composed of fruit-bearing trees such as coconuts, cacao, mango and multipurpose crops such as bananas and bamboo, forming dense forest-like assemblies of trees and shrubs either in patches or corridors enclosing the farm. Minimal activity was observed in this zone except for the occasional harvesting of fruits and timber when needed. In Malaysia (Ismail & Affendi 2015), the concept of food forest is often applied in urban environments to reintroduce biodiversity and promote food security. A fairly recent concept, The Picasso Food Forest in Italy is one example of a well-documented case study of a food forest that has provided a habitat for plant and wildlife species as well as nurseries for heirloom seed varieties (Riolo 2018).

Zone 5. The last zone observed in permaculture designs is the 'wilderness' zone. Often located outside of the farm property and beyond private management, it is still considered by practitioners as part of the overall design plan. The wilderness is more of a 'philosophical' feature of the permaculture landscape that provides the practitioner with design inspirations from nature. Examples of which are the montane forests in Olaussen, the coastline in Alpas, the mangroves in Glinoga and Nature Sanctuary, and the mountain range in Lorenza's. For farms with a wilderness within the property such as in Cabiokid and Jubileeville, the zone functions to reintroduce biodiversity. Biodiversity conservation in agroecosystems is the closest parallel to this concept (Piratelli et al. 2019). Since Zone 5 as a design feature is often beyond farm management, the practical use of this zone has not yet been formally studied in scientific literature.

Figure 4. Zone 1 garden zones are characterized by mixed cropping systems of annual and perennial species for subsistence and aesthetic functions. Raised beds (some with unique curved features), hugelkultur, and mulching are common techniques.

Figure 5. Cash crops in the Zone 3 landscape were mainly characterized by rice (C, D, H, I). In other sites, fruit trees like coconut and banana interfaces into the food forest in Zone 4 (F, B). Some sites deviate from the pattern with raised beds of annual vegetables (A) and a garden of ornamental plants (G).

Figure 6. The food forest landscape in Zone 4 is characterized by mixed perennial crops from the forest floor, understory, and canopy. In one site it is integrated with organic coffee trees (I). The zone serves as a source of food, fuelwood, and building materials. It also functions as a wildlife corridor, windbreak (shelterbelt), and soil erosion control.

Zoning in the Philippines, from zones 0 to 5, are consistent with existing literature (Mollison 1988; Hemenway 2009; Whitefield 2004; Kruger 2015; Bhandari and Bista 2019). However, the distinction between Zones 2 and 3 becomes obscured because livestock and other farm animals graze in the field during the fallow period. While there is no specific research yet on the effectiveness of strategically placing agricultural components in zones to increase crop productivity and resilience in permaculture farms (Krebs and Bach 2018), time-tested socio-ecological practices such as *satoyama* in Japan and the *muyong* system in Northern Philippines has proven that subsistence farming, cash crops, and woodlots can sustainably coexist on mosaic landscapes to provide food security and biodiversity (Buot and Osumi 2004). In Europe, a non-governmental scheme called Conservation Grade, suggested that nature (or Zone 5 - Wilderness), should comprise at least 10% of farm areas (Science for Environment Policy 2017).

Shapes and land area of zones also varied from each site. Zoning as a practice optimized the movement patterns of people, maximizing duration of interaction in nearby zones while avoiding frequent visits to areas that have self-sustaining biotic components like perennial crops (i.e. coconuts) and abiotic features (i.e. ponds). The zoning strategy was reported to be especially effective in permaculture sites with large land areas and limited manpower such as in the cases of Nature Sanctuary, Cabiokid, and Glinoga. Knowledge on permaculture zones remains largely confined within the theoretical assumptions from Mollison (1988). Whether this design pattern has been accurately incorporated into the farm management of permaculture landscapes has yet to be the subject of further scientific study. However, a similar landscape zone pattern (composed only of three zones: economic zone, combined zone, and natural zone) as proposed by Ferwerda (2016) mirrors permaculture zoning albeit in a larger landscape scale as demonstrated in landscape restoration projects in Spain, South Africa, Australia, and The Netherlands.

Identified landscape components

Component distribution. Figure 7 shows the number of landscape components observed in each zone. Components that were frequently used (i.e. houses, vehicles) and those in need of closer attention (i.e. vegetable crops) were located in inner zones (0-2). Outer zones contain components that only need minimal attention such as fruit trees and other perennial species.

Component categories. Table 2 reports a total of 1,182 system components recorded in all twelve sites with an average of 99 components per site. Among all sites, Glinoga had the most number of total components with 133 suggesting characteristics of a diverse farm landscape. In contrast, Jubileeville, a residential property, had the least number of total components with 56. The most number of components observed were biotic (678) followed by technological components (244) which demonstrates how daily life and farm management is supported by the use of technology. On the other hand, socio-economic components recorded the least number due to limited infrastructure for on-site agribusiness operations through 10 sites were promoting agritourism and ecotourism. The dominance of biotic components in 90% of study sites demonstrated how permaculture designs emphasized biodiversity in the design of its landscapes which are complementary to those implementing diversified farming systems in the US (Ferguson and Lovell 2017), socio-ecological landscapes in Bulgaria (Brawner 2015), and *satoyama* in Japan (Chakroun and Droz 2020). This diversity of components on the landscape is a stark contrast to the design of monoculture farms (Dmitri et al. 2005).

The 'abiotic' components observed included physical land features (i.e. hill slopes in Glinoga and Lorenza's, swales in Nature Sanctuary and Jubileeville) and water bodies (i.e. ponds in Cabiokid and Tara Farms and irrigation canals in UmaLeng). Also known as continuous landscape elements, these landscape components were either naturally-formed or manmade features designed according to the existing topography found in Zones 1 to 4. This technique of incorporating natural features was especially advantageous to farms with uneven or sloping landscapes (i.e. Glinoga, Jubileeville) to store and maximize rainwater (Ekka et al. 2021). In cases wherein the landscape is on level ground, 'earthworks' were performed to provide contours and gradations to direct water flow into man-made ponds for irrigation (Vico et al. 2020). Such were the cases in Cabiokid and Nature Sanctuary. Similarly, a design called 'borehole permaculture' in Malawi uses the same principle to avoid creation of stagnant ponds from spilled water which is diverted to irrigate gardens (Rivett et al. 2017).

Soil was also considered as an abiotic component. Results of the colorimetric soil analysis using a rapid soil test kit (Detera et al. 2014) reported generally sufficient levels of soil pH, nitrogen, phosphorus, and potassium for crop production across all sites as reported in Table 3. Given its 'continuous' nature, abiotic components are expectedly few on the landscape but they serve a central function for the spatial arrangement of other components. Similar to soil, waterways are also abiotic components. The Mekong river system is an example of a waterway abiotic component that provides multiple ecosystem services for the benefit of rice and aquaculture farm systems in the Lower Mekong Basin (LMB) which includes countries such as Thailand, Lao-PDR, Cambodia, Vietnam (USAID 2016).

'Biotic' components were found to be the most abundant in the landscape with an average of 57 per site. Although not all biotic components documented were cash crops, this was a significantly large number compared to commercial farms in the United States which only have an average of one crop per farm (Dmitri et al. 2005). Even diversified coconut farms in the Philippines only have 2 to 4 crops per farm (PCARRD 1993). Among those considered as biotic components were plant species, farm animals, wildlife, and the people themselves who live and work on the farm. Components that need minimal attention like grazing livestock (i.e. pigs, goats, carabaos) and fruit trees were situated in Zones 2, 3, and 4. Integration of mixed species (Kremen and Miles 2012) was found to be beneficial to the permaculture landscape. Examples of these were native pigs in Tara Farms which consumed excess vegetation and the mangrove forest in Nature Sanctuary which provided subsistence to the household and habitat for avifaunal species. In the US, the integration of livestock (Zone 2) into corn cropping systems (Zone 3) was found to increase soil organic matter and nutrient content (Maughan et al. 2009). Whereas in Asia, fish were integrated into rice paddy systems to regulate weed growth and pests. Fish as a biotic component also increased nutrient availability in soil and improved crop yields (Berg 2002).

Table 4 reports that all permaculture sites reported high crop diversity in terms of the number of plant species observed (>20-65) in a 1-ha sampling area. Twenty-one (21) species were documented in the Eco-house, the lowest species richness (SR), while 65 species were recorded in Glinoga, the highest recorded SR. Shannon-Wiener Diversity Index (H) revealed that Aloha House was the most diverse with a score of 0.311 while Nature Sanctuary had the lowest with an index score of 0.583. Analyzing the ratio of plant species per plant category showed that the 'vegetable/cereal crop' use category dominated the landscape in 50% of permaculture sites. On the other hand, 20% of sites were characterized by 'tree/fruit-bearing crops.' In all sites, perennial species were the most abundant with 75-95% of the total plant species found on the landscape. These results validate that permaculture landscapes rely on the cultivation of less-intensive perennial species (Mollison 1988). In the US, 35 permaculture farms were documented by Ferguson and Lovell (2017) to rely on a mix of annual and perennial crops together with farm animals. In South Africa and Zimbabwe, Didarali and Gambiza (2019) reported that crop diversity increased significantly upon practice of permaculture. In Indonesia, permaculture farms were reported by Putro and Miyaura (2020) as having a high degree of farm-level plant diversity with >25-100 species recorded in four farms.

Colocasia esculenta (taro) (Ahmed et al. 2020) and *Capsicum frutescens* (chili) (Yamamoto and Nawata 2005) were the most common crops found in 10 sites. Both species were said to be easily propagated either intentionally or unintentionally according to interviews. *Colocasia esculenta* was observed in low elevation water-logged areas while *Capsicum frutescens* was reported to be propagated via droppings from chickens and birds according to practitioners. *Annona muricata* (guyabano) was the most common fruit-bearing tree found in 9 sites. *Annona muricata* was a multifunctional tree used by practitioners that they claim to provide many health benefits. The fruit eaten is fresh or made into juice concentrate while the leaves and bark were steeped for tea.

Table 2. The total number of observed landscape components per site arranged by category. Glinoga has the most number of components (133) while Jubileeville had the least (56). Sites have an average of 99 landscape components with biotic category being the most abundant with an average of 56.5 per site.

Site	Component category						
	Abiotic	Biotic	Cultural	Manmade Structural	Socio-economic	Technological	Total
Aloha House	1	76	2	10	5	14	108
Alpas	5	69	3	14	1	14	106
Cabiokid	7	38	1	30	3	32	111
Eco-house	1	26	2	5	2	46	82
Glinoga	9	67	7	20	3	27	133
Jubileeville	5	30	2	7	0	12	56
Kai Farms	1	63	4	6	3	31	108
Lorenza's	3	54	1	4	2	5	69
Nature Sanctuary	3	40	14	14	1	33	105
Olaussen	2	83	4	7	7	3	106
Tara Farms	6	59	6	13	1	13	98
UmaLeng	3	73	6	3	1	14	100
Total	46	678	52	133	29	244	1182
Mean	3.83	56.5	4.33	11.08	2.42	20.33	98.5

Table 3. The soil test reported that the soil profile was generally suitable for planting crops with a soil pH range of 6 to 7.6. Soil samples were collected from September to November in 2018 during the rainy season.

Location	Parameters			
	pH	N	P	K
Aloha House	7.6	Medium	High	Sufficient
Alpas	6.8	Low	High	Sufficient
Cabiokid	6.0	Low	High	Deficient
Eco-house	7.6	Medium	High	Sufficient
Glinoga	6.0	Low	High	Deficient
Jubileeville	6.4	Medium	High	Sufficient
Kai Farms	6.4	Medium	High	Sufficient
Lorenza's	6.0	Medium	High	Deficient
Nature Sanctuary	7.6	Medium	Low	Sufficient
Olaussen	6.0	Medium	Low	Sufficient
Tara Farms	6.0	Medium	High	Deficient
UmaLeng	6.2	Medium	High	Sufficient

Bambusoideae was found in 8 sites with its young shoots consumed as *labong* and its stems used as construction materials for making houses and furniture. The plant also functioned as living fences and windbreaks. *Abelmoschus esculentus* (okra) is an easy-to-grow vegetable that was found in 7 sites. Okra's resilient characteristics as a perennial crop makes it a favored high-value crop for household consumption and selling. *Carica papaya* (papaya), *Cucurma longa* (turmeric), and *Moringa oleifera* (malunggay) were also documented in 7 sites. *Ipomoea aquatica* (kangkong) and *Solanum lycopersicum* (tomato) were found in 6 sites and were reported to be a regular part of the daily diet. Table 5 shows *Gallus gallus domesticus* (domestic chicken) was the most common type of poultry found in 6 sites while *Sus philippinensis* (*Baboy ramo*) was a common livestock observed in 4 sites.

In addition to plants and farm animals, bird species were also observed in all sites. Birds are an important component of the ecosystem as pollinators (Ford et al. 1979) and biocontrol (Lourenco 2021) for pest management in a permaculture landscape (Table 6). The role of birds in the permaculture landscape or agroecosystems in general needs to be studied further to determine its net effects (Olimpi et al. 2020).

Majority of 'manmade structural' components were found in Zone 0 but was also recorded in Zone 1 as seedling nurseries (Lorenza's, Laguna, Kai Farms); in Zone 2 as animal sheds (specifically for pigs in Tara Farms, Cabiokid, Aloha House); and in Zone 3 as a rice mill (Cabiokid). Although farm infrastructure is common components in an agricultural landscape, permaculture design allows manmade structural components to blend into the natural landscape (Singh and Nayyar 2015) with the use of renewable and locally available materials like *Bambusoideae* sp. (bamboo), *Corypha elata* (buri palm), and *Saribus rotundifolius* (*anahaw*) in combination with more traditional construction materials such as concrete and lumber. Use of natural materials, especially bamboo, in architecture are having a revival in Asia because of its abundance, multifunctionality, and sustainability as locally available materials. (Emamverdian et al. 2020; Maslucha et al. 2020).

'Technological' components documented machines, gadgets, and installations on the landscape. Components also include garden tools (shovels, trowels, rakes, garden hose) and appropriate technologies (trellises, raised beds, mulches, fertilizers, rainwater harvesters, etc.). These comprise the second most abundant category next to biotic components with an average of 20 technologies per site. Presence of technologies on the landscape demonstrated how permaculture practitioners interacted with the natural environment through the use of tools (Petri and Faust 2021). Furthermore, technological components created the connectivity of different components on the landscape. Examples of technology in other countries are projects such as borehole-garden permaculture in Malawi (Rivett et al. 2017) and the use of marine permaculture arrays (MPAs) in seascapes in Oman for climate change mitigation (Von Herzen et al. 2017).

'Socio-economic' components (Genus et al. 2021) were the least common on the landscape with only an average of 2 per site. The low number was expected because it only included infrastructures or spaces that generated income for the household such as retail stores, food processing facilities, and training/education facilities. Aloha House, Eco-house, Cabiokid, and Olaussen had small stores selling locally-made products. In Glinoga, a facility is dedicated to food processing. Alpas has a restaurant that serves local food while UmaLeng has a workshop facility for making local soap. These components were integrated into the permaculture landscape to initiate community engagement and provide an outlet for sharing and trading goods and services (Putro and Miyaura 2020).

Socio-economic components were also responsible for the financial stability of a permaculture design (Akhtar et al. 2015; Vitari and David 2017). Farms with limited revenue streams may struggle financially in the long term and must rely on other sources of income for working capital. The most common integration of socio-economic components into farm landscapes are agritourism and ecotourism services. Kitchen gardens in Thailand (Ip-Soo-Ching and Veerapa 2013), food and hospitality-related services in Indonesia (Putro and Miyaura 2020), are among the most income-generating components of permaculture farms.

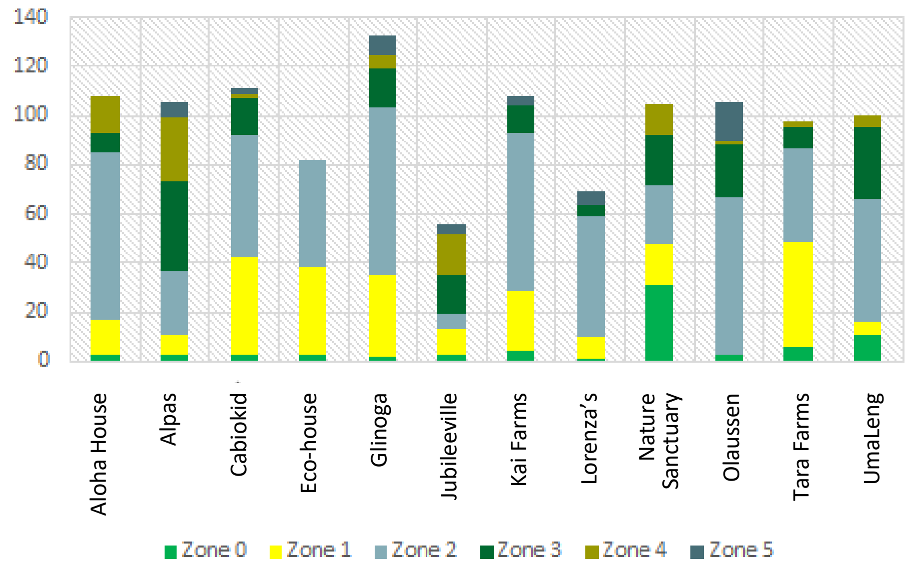

Figure 7. A stacked column chart shows the distribution of system components per zone. Zones 1 (garden) and 2 (grazing) report the most number of components

Table 4. Crop diversity per use category and crop life cycle. Data shows that Glinoga had the highest SR (65) and Eco-house had the lowest (21). Aloha House had the highest H index score (0.311) and Nature Sanctuary had the lowest (0.583)

Site	SR*	H**	Use category (%)						Life cycle		Total
			Feed crops	Herbs	Ornamentals	Fruit crops	Veg/Cereal crops	Weeds	Annuals	Perennials	
Aloha House	62	0.311	0.016	0.242	0.113	0.274	0.355	0.000	0.226	0.774	1.000
Alpas	45	0.345	0.000	0.067	0.311	0.378	0.244	0.000	0.133	0.867	1.000
Cabiokid	24	0.504	0.000	0.042	0.125	0.292	0.542	0.000	0.208	0.792	1.000
Eco-house	21	0.434	0.000	0.286	0.190	0.238	0.286	0.000	0.048	0.952	1.000
Glinoga	65	0.314	0.015	0.062	0.215	0.462	0.231	0.015	0.123	0.923	1.000
Jubileeville	48	0.334	0.021	0.021	0.333	0.458	0.167	0.000	0.104	0.917	1.000
Kai Farms	52	0.331	0.000	0.327	0.096	0.212	0.365	0.000	0.231	0.769	1.000
Lorenza's	58	0.356	0.017	0.121	0.259	0.293	0.190	0.138	0.172	0.828	1.000
Nature Sanctuary	25	0.583	0.000	0.040	0.040	0.600	0.320	0.000	0.120	0.880	1.000
Olaussen	36	0.444	0.000	0.083	0.083	0.278	0.556	0.000	0.250	0.750	1.000
Tara Farms	62	0.320	0.016	0.194	0.548	0.108	0.129	0.016	0.161	0.871	1.000
UmaLeng	56	0.377	0.000	0.214	0.214	0.196	0.339	0.000	0.107	0.893	1.000

Note: *SR = Species Richness; **H = Shannon-Wiener Diversity Index

Table 5. Types of farm animals documented in permaculture landscapes

Animals	Site						
	Aloha House	Alpas	Cabiokid	Eco-house	Glinoga	Tara Farms	UmaLeng
Gallus gallus domesticus (domestic chicken)	+	+	-	-	+	-	+
Sus philippinensis (Philippine warty pig) or *Sus scrofa domesticus* (domestic pig)	+	-	+	-	+	+	-
Capra aegagrus hircus (domestic goat)	+	+	-	-	+	-	+
Carina moschata (Muscovy duck)	+	-	+	-	-	+	+
Bubalus bubalis carabanesis (Philippine carabao)	+	-	-	-	+	-	-

Table 6. Avifaunal species observed in permaculture landscapes during the rainy season (September to November of 2018)

Site	Scientific name	Common name
Aloha House	*Rhipidura nigritorquis*	Philippine Pied Fantail
	Aplonis panayensis	Asian Glossy Starling
Alpas	*Lanius cristatus*	Brown Shrike
Cabiokid	*Pycnonotus goiavier*	Yellow-vented bulbul
Eco-house	*Dicaeum austral*	Red-keeled Flowerpecker
Glinoga	*Oriolus chinensis*	Black-naped Oriole
	Todirhamphus chloris	Collared Kingfisher
Jubileeville/ Tara Farms	*Passer montanus*	Eurasian Tree Sparrow
Kai Farms	*Merops americanus*	Rufous-crowned Bee-eater
	Cinnyris jugularis	Olive-backed sunbird
Lorenza's	*Rhipidura cyaniceps*	Blue-headed Fantail
	Merops philippinus	Blue-tailed bee-eater
	Orthotomus derbianus	Grey-backed Tailorbird
	Copsychus mindanensis	Philippine Magpie-Robin
Nature Sanctuary	*Nycticorax nycticorax*	Black-crowned Night Heron
	Cyornis rufigastra	Mangrove Blue Flycatcher
Olaussen	*Saxicola caprata*	Pied Bushcat
UmaLeng	*Amaurornis phoenicurus*	White-breasted waterhen
	Lonchura atricapilla	Chestnut Munia
	Ardeola speciosa	Javan Pond Heron

Finally, findings showed that permaculture landscapes have 'cultural' components (or 'cultural artifacts' in sociology) that identify the practitioner's personal values and religious beliefs (Ingram et al. 2014). Notable examples of such are Stations of the Cross in Nature Sanctuary and a chapel in Mountain Province which signify Christian influences. In addition, cultural components also provide leisure and recreational activities for family and friends. Examples are swimming pools in Tara Farms and Jubileeville and a basketball court in Glinoga. Although the documentation of cultural artifacts per se in permaculture is a relatively novel idea, cultural components are often expressed in the preservation of traditional or indigenous farming practices (Lwogo et al. 2010) such as in the cases of Bulgaria (Brawner 2015), El Salvador (Millner 2017), and Japan (Chakroun 2019).

The dominance of biotic components in almost all sites indicated that biodiversity was prioritized in permaculture designs (Hirschfeld and Van Acker 2021) while technological components were integrated to support biotic functioning and vice versa. The abundance of both of these component categories demonstrated how permaculture practitioners in the Philippines relied on technology, renewable resources, and the environment for daily needs.

In conclusion, the application of permaculture in farms is a strong example of sustainable agriculture in the Philippines. The way permaculture landscapes are structured into zones provides a diversity of components to support the cultivation of a variety of crops. In addition, design emphasis on biophysical diversity is a significant departure from the common practice of monoculture in conventional farming thus creating heterogeneous landscapes that resemble the appearance of forests more than farms. However, the scale of permaculture design is still limited to smallholder farms and home garden landscapes.

In theory, permaculture is scalable but examples of whole communities benefiting from the collective design efforts of multiple practitioners originating from a common locale have yet to be documented in the country. In addition to scale, annual crop yield from mixed cropping and agroforestry systems and the income derived from diversified revenue streams generated by farm multifunctionality were not included in the study.

Permaculture has yet to receive enough attention in order to attract institutional support to promote its practice. But with more research, especially on local examples of successful practitioners and their landscape designs, permaculture can provide the necessary design framework for restructuring our agricultural landscapes into diverse and productive ecosystems and redefining our relationship with nature.

ACKNOWLEDGEMENTS

The authors would like to thank The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Philippines for funding this project; the permaculture practitioners who participated in the study; and the research assistants who helped in the processing of data.

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