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Biodiversity of Soil Mesofauna Associated with the Design of Home Gardens in Mapuche Agroecosystems—Case Study in the Araucanía Region

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Abstract: Home gardens play a transcendental role in food sovereignty, for which the management of habitats above ground and underground are complementary strategies. This study aims to compare the biodiversity of soil mesofauna groups between agroecosystems with a conventional and an agroecological design. Through the combination of quantitative (plant inventories) and qualitative (mobile interviewing and talking maps) techniques, the units of this study was described. Soil samples were mounted in a Berlesse–Tullgren system, and the abundance, richness, diversity, and equality of soil organisms were determined. The relationships between functional groups were compared taxonomically and biocenotically. The results indicated higher equality in the conventional home garden, while the communities studied present a medium taxocenotic similarity, without great biocenotic differences. The diversity and richness of taxa, as well as the abundance in each group identified, were higher in the agroecological garden, which had more medicinal and aromatic plants.

Keywords: agroecology; functional biodiversity; women farmer; ancestral knowledge

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1. Introduction

Home gardens, both in their countryside and urban expressions, play an important role in the preservation of agrobiodiversity as a basis of food sovereignty. Home gardens reflect the materialization of a series of transformation processes in the territory [1], which are based on complex knowledge systems, their agricultural management and the capacity of family agriculture to be a diversifying driver and a source of agrobiodiversity creation over time [2]. Home gardens have become learning spaces for citizens in general [3] through formal educational processes for students [4] and collective self-education territories through a critical extension model that promotes the ecology of knowledges [5].

Home gardens are important for the generation of community [6]; the reconstruction of the social fabric [7]; the development of strategies oriented to self-consumption [8]; and the protection of the genetic heritage [9] of unique varieties of highly adaptive, culinary, ritual, symbolic and agricultural value [10]. Home gardens are considered spaces for exploring the territory [11] and occupying the public space, as well as for reconnection with nature. From the perspective of aesthetics [12] and the appreciation of indigenous cultures [13], and in relation to emotional aspects, life stories and work experiences, these systems promote an ethical positioning of female farmers [14]. Home gardens are, definitely, a place of meeting that strengthens the social fabric, nurtures spirituality and reflects the identity of women, giving them sovereignty in their practices [15]. This diversity of purposes, motivations and expressions that unfold in home gardens constitutes the resilience of agroecological initiatives [16].

From an agroecological perspective, the establishment of sustainable production systems is conducted through the design of sites based on principles that encourage ecological processes rather than mechanically repeated protocols, models or recipes. Within these principles, the stimulation of soil biology stands out [17,18] considering that the diversity—especially underground and part of the system—provides a variety of ecological services that have an impact inside and outside the plot [19]. The diversity of soil life—as an integral part of the agroecosystem—is closely related to the diversity of plants in the soil, which allows for the generation of these optimal conditions. Both elements (diversity above and underground) are considered 'the pillars' of a strategy for converting a conventional production system into a sustainable one [20].

The management strategies of the aboveground and underground habitat are complementary, since by potentiating positive ecological interactions among their components, ecosystem functions are potentiated through the development of emerging qualities that mainly derive from diversity management.

In this sense, diversity planned by farmers plays a fundamental role. This is achieved through multiple spatial and temporal designs, for example, through the arrangement of intercropping, with crops combined in rows such as covers, barriers and living fences, among others, using a diversity of multifunctional plants: medicinal, aromatic, culinary, ecological service providers, and fodder [21].

The site design of an agroecological system follows some structural arrangements based on the functional diversity of organisms (plants and animals) present in an agroecosystem—aboveground and underground—and their contribution to an ecosystem function. This functional diversity of redundant nature [22] gives resilience to an agroecosystem, which is an essential attribute of sustainability [23].

The design of farms under more specific agri-environmental schemes requires concrete spatial knowledge [24], as this is more important to understand the links between key species or functional groups rather than focusing on species diversity [25]. In this sense, the plant species most valued by farmers are those that fulfill multiple economic and agricultural functions, including the positive influence on soil quality [26]. However, many of the properties and ecosystem services of these multifunctional plants are unknown or ignored in research on property designs [27].

The experimental designs used often do not allow for adequate generalizations; therefore, it is reasonable to suggest using coevolved communities to investigate the different roles of functional groups [28]. At the plot and farm scale, biodiversity is unlikely to be maintained for purposes other than direct use or benefit, except for traditional systems, where intrinsic values, such as social customs, continue to provide reasons for maintaining diversity [28].

For agroecological and more holistic agrarian systems, cropland is a specific ecosystem that reflects the worldview and the environmental and human nature of each region where agricultural activity is practiced. Like any system, it evolves over time, conditioned by environmental factors that are present in a specific scenario, and generally, in crop soils, it remains dynamic, being determined by its utilization imposed by socioeconomic and cultural conditions [29].

Local ecological knowledge of communities about the effect of different species on soil quality, species interactions and the role of vegetation in maintaining agricultural productivity, is an important component of the adoption and success of agroecological systems [26]. This highlights the relevance of sociocultural factors in farmers' decisions in the design of their farms and their influence on edaphic communities [30].

In recent studies, the importance of growing home gardens to increase agrobiodiversity has been highlighted. The authors of [31] note the small amount of information available about agrobiodiversity in home gardens in Chile, specifically on topics such as intraspecific diversity, preservation states, and the presence of wild plants and animals in these biocultural areas. Regarding animals, research about soil mesofauna is much scarcer. In this scenario, the present research seeks to answer the following question: Are there differences in soil communities derived from the agroecological practices carried out by women farmers in the design of their farms? Therefore, the objective of this study is to compare the biodiversity of soil fauna groups in home gardens found in agroecosystems with a conventional and an agroecological design.

2. Materials and Methods

This study was conducted in the Juan Queupán community, within the framework of the Global Program for the Preservation of Farming Biodiversity (in Spanish, CBDC) that the Education and Technology Centre for the Development of the South (CETSUR) created in the 1990s with indigenous (Mapuche) women in order to preserve the food and agriculture heritage, the local biodiversity and the ancestral knowledge from an agroecological perspective [32]. These actions were taken with the active participation of female farmers in reflection, interaction and iteration spaces [33] through participative methodologies that enabled the dialogue of knowledges [34,35].

The community is located 12 km from Temuco (route to Chanquín), in the Boyeco area, Araucanía region (N 26, 22°; S 78, 42°; E 41, 29°; O 43, 27°) (Figure 1). The study was conducted in three stages: (1) the selection and description of study units; (2) the collection of soil samples in these units for their subsequent processing; and (3) the identification, classification, and quantification of soil organisms.

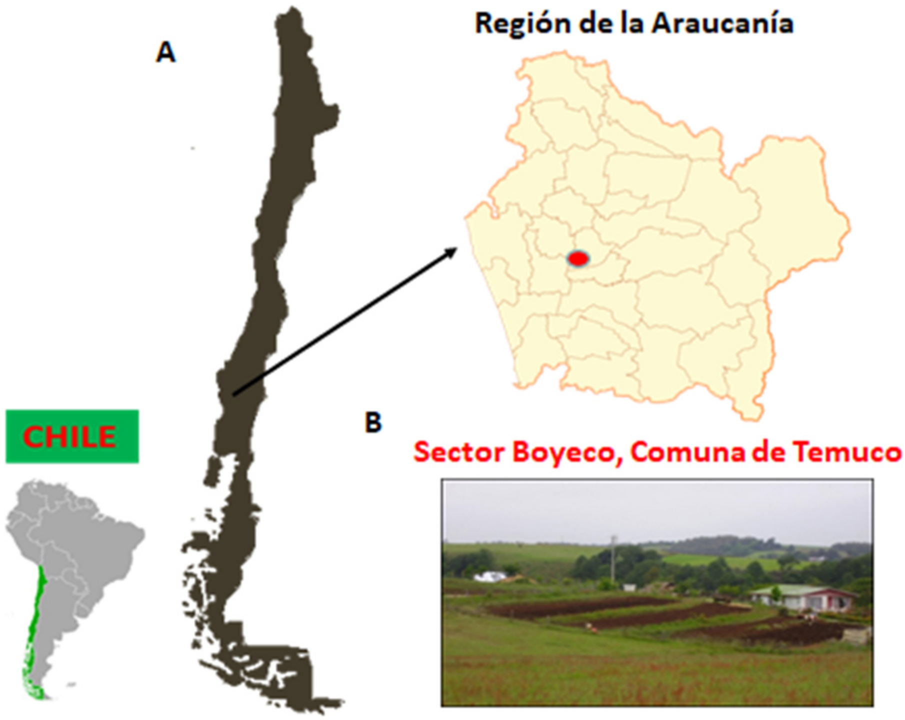

Figure 1. (**A**) Location of the study. (**B**) Productive systems.

2.1. Selection and Description of Study Units

The units of analysis were a conventional system (CS) and an agroecological system (AS). The two study units correspond to Family Farming Units (FFU) integrated by nuclear families whose main economic activity is the agricultural production of their land for self-consumption, the partial and occasional commercialization of the surplus, and the exchange of some products [32].

The ethnoecological description [36] was centred on the design of home gardens (diversity of plants and their spatial and temporal arrangements, garden management and technologies used). To this end, native categories were established (local or own) [37], obtained from a previous reflective and critical ethnographic exercises [32]. Data collection was conducted with the female members of the two families owning each FFU [38] through a mix of tools [39], namely quantitative tools (inventories) and qualitative tools (mobile interviewing [40]; talking maps [41]) (Figure 2).

Figure 2. Images of fieldwork to describe the gardens. (Source: Maricel Silva).

Both units (CS and AS) belong, from a climate perspective, to district No. 17 of Temuco, with an average annual temperature of 11.7 °C (average maximum of 24.1 °C and minimum of 3.9 °C). The average annual rainfall is 1209 mm, with a water deficit of 472 mm, which implies a dry period with high risk of droughts between November and March. Regarding geomorphological characteristics, soils are of volcanic origin, red clay of the Metrenco series [42], whose main characteristics are their complex slope hills (4–15%), regular to good drainage and a predominant use capacity of III and IV.

The physicochemical characteristics of the soil (Table 1) are similar for both units, which according to [43] correspond to average values for this type of red clay soils of volcanic origin.

Table 1. Soil analysis for different plots (1 and 2) of AS (agroecological system) units and CS (conventional system) units.

Parameters	AS Plot 1	Plot 2	CS Plot 1	Plot 2
pH ($-\log[H^+]$)	6.20	5.55	5.06	5.58
Organic Matter (%)	10.85	5.74	12.03	7.86
CEC (MEQ/100 g)	17.23	6.14	9.52	6.14
Al Saturation (%)	0.03	4.69	0.93	2.51

Source: [36].

2.2. Collection of Soil Samples

Soil fauna communities were assessed and compared in both units. To this end, samples were randomly collected within the first 10 cm of soil in different areas of the garden with six replicas of 188.5 cm^3 each, and 24 replicas on each farm [44]. The samples were collected and stored in polyethylene bags and taken to the laboratory for processing. In the lab, they were mounted in a Berlesse–Tullgren system for 7 days in order to ensure the extraction of soil organisms [45]. Organisms were collected in 75% alcohol and stored in glass vials.

2.3. Identification, Classification, and Quantification of Soil Organisms

Subsequently, organisms were identified at the order and sub-order levels and quantified under a Nikon SMZ 660 stereo (binocular) microscope. The soil communities of both study units were assessed through the Shannon–Wiener Diversity Index (H′) and Evenness Index (J), and then compared taxonomically and biocenotically through the Jaccard Similarity Index (S_J) and Winer Index (S_W), respectively. For the Winer Index, the following formula was used:

$$S_W = \frac{\Sigma xi * yi}{\sqrt{\Sigma xi^2 * \Xi yi^2}}$$

where xi are the individuals of species i in the location x, and yi are the individuals of species i in the location y [46].

3. Results

3.1. Site Designs

The systems analysed are characterized by a design that, in the case of the conventional system, presents different plots intended for the main monoculture of *Avena sativa*, *Triticum aestivum*, *Lens culinaris*, *Cirsium arvense*, and *Pisum sativum.* In the agroecological system, instead, plots are used for associated crops, mostly *Chenopodium quinoa*, *Phaseolus vulgaris*, *P. Coccineus*, *P. sativum*, *Avena sativa* and *Vicia faba*, and for the polycropping of *Zea mays-P* and *vulgaris-Helianthus annus*, especially the varieties and lines of the Phaseolus genus.

Fertilization in the conventional system is restricted to the use of manure in some crops and, more commonly, the application of urea and triple superphosphate. Meanwhile, in the agroecological system, compost made from home waste, harvest residues and manure (poultry, rabbits and cattle) are employed.

Regarding the diversity of plants in the gardens, a larger number of plant species and varieties is found in the Agroecological System (AS) compared to the Conventional System (CS), with AS quadrupling CS (Supplementary Tables S1 and S2) despite the same percentage of botanical families predominating in both systems (Figure 3).

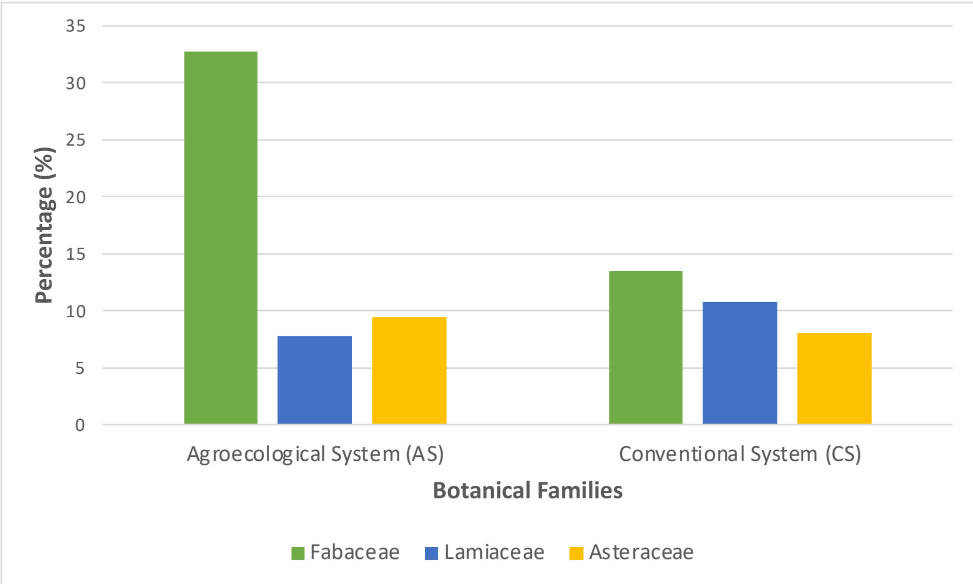

Figure 3. Predominant botanical families present in the gardens (%).

In addition, the uses (properties) of the plants mentioned by the female farmers have a larger number of species and varieties in the AS for four out of five categories established, in which culinary and medicinal/aromatic use stand out with the highest values (Figure 4).

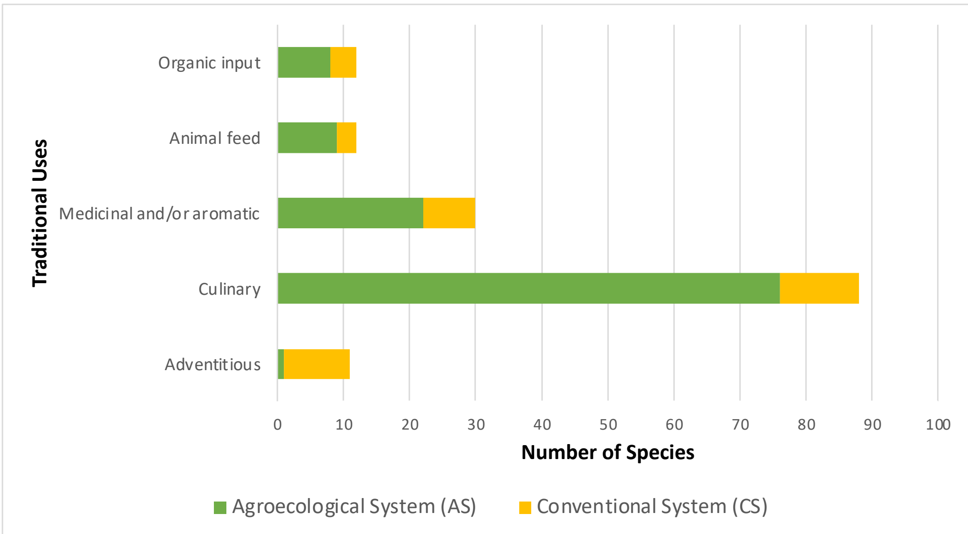

Figure 4. Traditional uses of plants in the gardens.

3.2. Underground Biodiversity

The agroecological system presents a higher total abundance (N) of individuals and in each group identified (Figure 5 and Table 2), as well as a greater diversity (H′) and richness of taxa (S) (Table 3). Equality (homogeneity, J), in turn, reports a higher value in CS (0.73), indicating that in AS, relative abundance tends to be less equal and is determined, in this case, by a higher abundance of acari groups (Table 2).

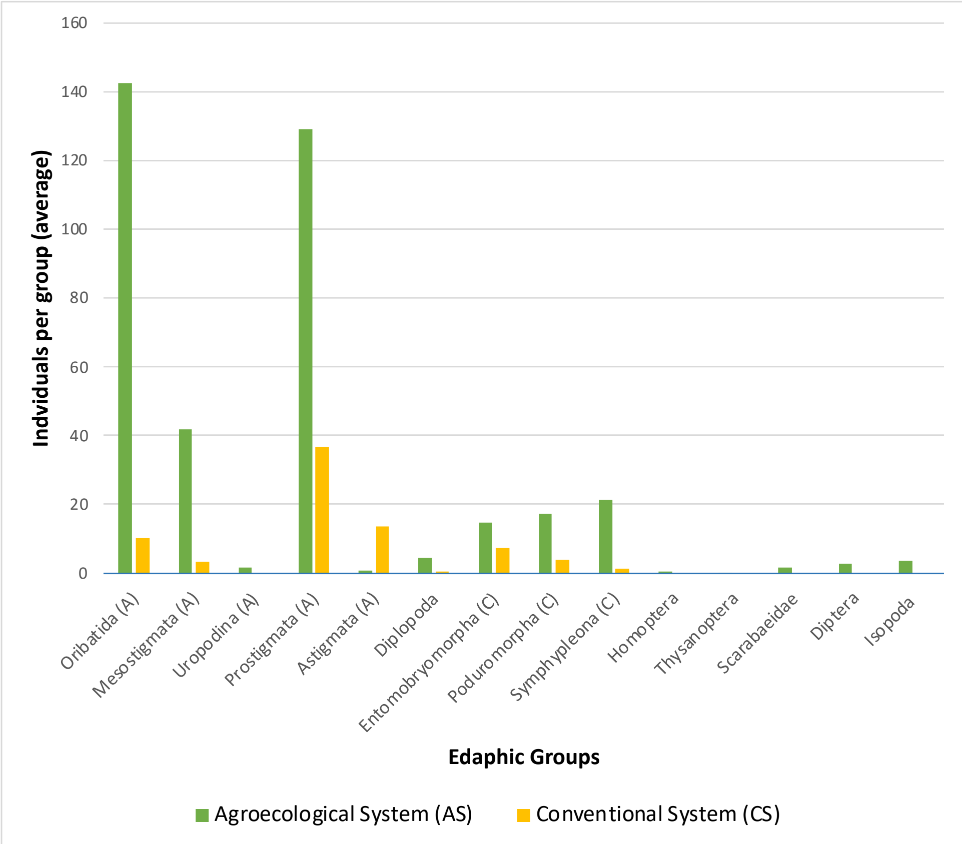

Figure 5. Number of individuals by edaphic group under AS and CS designs. (A) = Acari; (C) = Collembola.

Table 2. Total abundance, mean and standard deviation of each taxon and for each study unit (CS = conventional system; AS = agroecological system); (A) = Acari, (C) = Collembola.

Taxa	CS			AS		
	Total	**Mean**	**Standard Deviation**	**Total**	**Mean**	**Standard Deviation**
Oribatida (A)	51	10.2	3.421	713	142.6	39.759
Mesostigmata (A)	17	3.4	1.673	209	41.8	13.864
Uropodina (A)	0	0	0	8	1.6	2.51
Prostigmata (A)	184	36.8	1.483	646	129.2	111.547
Astigmata (A)	68	13.6	14.502	4	0.8	1.304
Diplopoda	2	0.4	0.894	22	4.4	5.32
Entomobryomorpha (C)	36	7.2	4.207	73	14.6	7.092
Poduromorpha (C)	19	3.8	2.683	86	17.2	12.716
Symphypleona (C)	6	1.2	0.837	107	21.4	7.335
Homoptera	0	0	0	2	0.4	0.894
Thysanoptera	0	0	0	1	0.2	0.447
Scarabaeidae (Coleoptera)	0	0	0	8	1.6	3.578
Diptera larvae	0	0	0	13	2.6	3.05
Isopod (Crustacea)	0	0	0	18	3.6	2.191

Table 3. Diversity indices for CS and AS. Biocenotic (S_W) and taxocenotic (S_J) relationship between CS and AS (CS = conventional system; AS = agroecological system).

Index	CS	AS	CS/AS
Richness (S)	8	14	
Abundance (N)	383	1910	
Shannon-Wiener (H′)	2.21	2.31	
H′ max	2.99	3.81	
Evenness (J)	0.73	0.61	
Jaccard (S_J)			0.57
Winer (S_W)			0.79

The value of S_J (0.57) (Table 3) indicates that the AS and CS communities present a medium taxocenotic similarity, among which acari the absence of uropodina stands out in CS. This group, together with oribatida [47], is an indicator of a highly productive soil. Therefore, the greater abundance of oribatida in AS compared to CS and the absence of uropodina in CS indicate a better condition of the soil in systems that have been designed under agroecological principles. The highest oribatida and diplopoda values in AS reflect a better condition of the biological activity in the AS soil, as these organisms play the role of decomposers.

The value of S_w (0.79) indicates little biocenotic differences between communities (CS and AS), with a similarity in the acari/collembola ratio [48] of 5.25 for CS and 5.94 for AS. However, the biocenotic relationships by the acari group show better soil conditions for AS (Table 4). Concretely, the oribatida/astigmata balance [49] indicates a higher level of soil disturbance in CS (0.75) than in AS (178.25) due to a higher abundance (absolute and relative) of astigmata in CS. Regarding the oribatida/prostigmata ratio [50], values indicate a higher imbalance in the SC community (0.27) than in the AS community (1.1) due to the relative dominance of prostigmata organisms. In the case of the astigmata/mesostigmata ratio [51], values are higher in CS than in AS (4.0 and 0.01, respectively), indicating a higher alteration or instability of the soil medium in the CS community.

Table 4. Values derived from the ratio established between functional groups for CS and AS (CS = conventional system; AS = agroecological system).

Ratio between Groups	CS	AS	Author
Acari/Collembola	5.25	5.94	[47]
Oribatida/Astigmata	0.75	178.25	[48]
Oribatida/Prostigmata	0.27	1.1	[49]
Astigmata/Mesostigmata	4.0	0.01	[50]

4. Discussion

The differences and similarities in the biodiversity of the soil mesofauna associated with system design can explain based on indirect interventions [52] performed by farmers and agricultural works in their gardens: (a) plant diversity, (b) the spatial and temporal arrangement of the same, and (c) the management through different techniques and practices. These categories established from the results have a high agreement with those described in recent similar studies [53].

4.1. Plant Diversity

A high diversity of plant species increases the diversity of soil microfauna [54]. The biodiversity expressed above a complex ecosystem has its expression under, in the soil, in the diversity of species that coexist, intertwine, interlock, alternate, overlap, ascend and/or combine, forming a web [55]. In this case, the higher diversity, individual abundance and taxa richness present in the AS soil community is directly related to the larger number of plant species and varieties, with AS quadrupling CS. In this sense, species diversity aboveground in the agroecosystem is directly related to the species diversity underground, which expresses as soil quality [55]. In this case, the different varieties of *Ph. vulgaris* present in AS should be noted.

An increase in species richness in a farming system introduces the possibility of including species that positively contribute to the general operation of the agroecosystem [56]. The direct introduction of new species as a way to manage agroecosystems and expand ecosystem functions and services modifies the associated diversity, for example, between soil biota and adventitious flora [57]. In this case, the higher flora diversity in AS, together with the establishment of a direct relationship with higher levels of soil mesofauna diversity and richness, is also associated with different levels of adventitious plants (Figure 4) and a lower level of pest and/or disease incidence [36] than CS.

4.2. Spatial and Temporal Arrangement of Cropped Functional Biodiversity

Studies about agroecosystem biodiversity have established that functional diversity is more relevant than species diversity itself [58]. Concretely, this is associated with the ecological services that such biodiversity can offer agroecosystems [59]. In fact, the increase in species richness in a crop system increases the possibility of including species that positively contribute to the general operation of the ecosystem through ecological services [56].

Agroecosystems can be managed to expand ecological functions and services through the direct introduction of new species, thereby modifying the associated diversity, i.e., soil biota and adventitious flora [57]. The intentional disturbance to the system (agroecosystem management) should be designed in such a way that a system develops a mechanism to recover from disturbances and continues with the main processes autonomously. If management aims to support biodiversity so the desired functions of the agroecosystem are achieved, both the biofunctionality and the functionality of biodiversity can contribute, i.e., biofunctionality implies species adapted to specific objectives, while diversity can increase the number of species responsible for processes in the agroecosystem. This prevents the system from being dominated by negative forms of biofunctionality such as weeds and pests [60].

The diversification of the agroecosystem implies incorporating regenerative components, such as the combination of plants in intercropping, agroforestry systems (crops and trees), and silvopastoral systems (animals and trees), using legumes as cover or rotation crops, etc. An organism community in an agroecosystem becomes more complex when a larger number of different plants are incorporated, generating more interactions between arthropods and associated microorganisms that are part above and under the soil food webs. The integrity of an agroecosystem relies on synergies between plant diversity and the soil microorganism community to optimize the decomposition and the renewal of organic matter [61].

The agroecological system studied does not only present high flora diversity but is also arranged in different ways spatially and temporally [62] through crop rotation using legumes, associated crops, intercropping and polycropping, in which medicinal and aromatic plants are located in different areas of the system, making it less vulnerable [36]. This interconnection between communities above and underground that is attributed to the complex design of the agroecological system studied is in agreement with other recent studies, in particular, the higher values in diversity and abundance in more complex designs and the increased abundance of acari and entomobryomorpha [63–65].

4.3. Management through Different Techniques and Practices

One of the techniques employed in an agroecological system's soil management is the production of biopreparations and the application of compost. The incorporation of compost has an effect on both microorganisms and fauna in the soil. The application of compost accelerates the soil biological activity and generates changes in the population density of collembola and acari, as well as in microbial activity [66]. As mentioned above, the changes in the plant community, driven by organic amendments and crops that provide ecological services, can affect the underground community and vice versa [67].

The highest levels of oribatida and mesostigmata (acari) and of entomobryomorpha (collembola) were found in the agroecological system, which incorporates compost in the soil [68,69]. Regarding the relationships between oribatida/astigmata, oribatida/prostigmata and astigmata/mesostigmata, the estimates suggest that in that soil groups that constitute stability indicators (oribatids and mesostigmata) predominated in the agroecological system [70]. These groups are favoured by the addition of organic matter and a larger soil coverage, stimulating the recovery of more stable conditions by the mesofauna. In this sense, the presence of uropodina in AS, despite being low, could be explained by the application of compost—as a cultural practice for soil management—as these organisms are common in these environments [71]. Conversely, in the conventional system, groups indicating soil instability and infertility (astigmata and prostigmata) predominated.

Finally, the similarities found between the studied systems (AS and CS)—both at the taxonomic and at the biocenotic levels—could be explained by the predominance of three botanical families in both systems (Figure 3), which would make the plant communities aboveground similar. Studies conducted in other agroecosystems in Chile indicate that the similarities between mesofauna communities present lower values (Sj and Sw close to 0), which is associated with plant communities that are very different from one another (naturalized prairie vs. monocrop) [72]. Conversely, mesofauna communities in the soil of organic monocrops present Sj and Sw values close to 1 [73,74]. The results of this study would confirm a tendency toward higher soil mesofauna diversity, abundance, and richness values in agroecosystems with greater flora diversity, which is complementary with increasing (taxo and biocenotic) similarity values in mesofauna communities associated with monospecific designs [30].

The verification of more abundant biodiversity of soil mesofauna associated with a more complex design contributes to the validation of a production form (peasant family farming)—based on agroecological principles—which through biodiversified systems guarantee the functioning of agroecosystems, allowing for their adaptation and self-organization.

However, the high complexity in design observed in the HS and the skills deployed are not only limited to a material dimension. The ethnic worldview, in this case, Mapuche, conceives the garden as a space of socialization and approach to nature and not only as a production plot [75]. The many ways of understanding the land from the perspective of women imply a resignification of such relationships—among others, from the subsistence approach where the essential element is the reproduction of life from which food sovereignty is built [76].

The woman supposes greater relevance to understand the sociocultural environment of the garden, since she is the one who dedicates more time to her work on the land and grows her experience. The garden is a space from which others are excluded, it can be considered the exclusive domain of a woman [77]. Therefore, the spatial and temporal dispositions present in the HS described above obey different relational processes based on the symbolic and, indeed, material experience of the garden.

The pluri-functionality that represents the design established in the SA and its complex structure are those that allow the provision of different benefits both to its family, to the community and to the ecosystems [78]. The establishment of complex designs based on a high diversity of plants in the AS responds to a simultaneous participation in different interrelated activities of production and care that depend directly on the surrounding ecosystems. This situation coincides with what was reported in other studies [79], which noted multitasking and a focus on managing biodiverse systems to fulfill production and care roles and achieve different degrees of resilience.

The exchange of seeds and knowledge of the management techniques and practices carried out by agriculture in the HS coincides with what was observed in recent similar studies [15] regarding the zealous care of the garden and the flow of products between friends and relatives.

Finally, the sociocultural and material knowledge of natural resource management in relation to local knowledge from a gender perspective has not been sufficiently valued.

These agroecosystems are the base of sustainable food systems, and therefore, the acknowledgement of what they represent to rural communities [80] and the strategies developed to manage agrobiodiversity [81] is fundamental in the scaling of these agroecological experiences and in the fair and responsible allocation of the value of the food we consume.

5. Conclusions

Based on the conditions under which this study was conducted, it is concluded that an agroecology-based agroecosystem with a biodiverse design, functional spatial-temporal arrangements and regenerative management presents higher values of soil mesofauna diversity compared to an agroecosystem with a conventional design mainly based on monocrops and the use of synthetic inputs.

Values of beta diversity for the communities assessed are similar for the acari/collembola ratio in both systems, which is characteristic of agroecosystems. Similarities are attributed to flora diversity, in which the same botanical families (*Fabaceae*, *Lamiaceae*, *Asteraceae)* predominate in both units.

Differences in the balance between acari functional groups (oribata, astigmata, prostigmata and mesostigmata) indicate a lower level of disturbance, imbalance and instability in the agroecological base system as this follows a more complex design that includes spatial arrangements (polycropping, associated crops, biological corridors and adventitious flora handling) and temporal arrangements (crop rotation), as well as soil fertility management based on the incorporation of some legumes, green manures and compost.

The results reveal the value of small family farms, particularly with a solid agroecological base, since despite not having a design as complex as that of CS, AS presents as a strategy that is very close to an agroecological proposal, which is distant from conventional techniques of input substitution and predominant monocropping without rotation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12091704/s1, Table S1: Plant species and varieties, their uses and location in site design for the Agroecological System (AS); Table S2: Plant species and varieties, their uses and location in site design for the Conventional System (CS).

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