AGROBIODIVERSITY AND ASSOCIATED TROPHIC INTERACTIONS AS AN INDICATOR OF SUSTAINABILITY IN PRODUCTIVE SYSTEMS OF ARGENTINE PAMPEANA REGION

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Abstract

Biodiversity is crucial in agroecosystems, as it makes them more efficient, stronger, productive and resilient. The aim of this work was to determine and compare the existing biodiversity in two different production systems: agroecological and industrial during 2018 and 2019 in the INTA Barrow (Buenos Aires, Argentina). Sampling of mammals, birds, arthropods and spontaneous vegetation were made in wheat and oat crops. Several parameters were estimated including abundance, density, richness, dominance, diversity and equitivity for each study group. The agroecological system presented higher density of birds and mammals, richness of arthropods and spontaneous species compared to the industrial system. The greater agricultural diversification in the agroecological system evidenced a more complex landscape structure, through the increase in the richness of spontaneous species and beneficial fauna that would increase the potential for biotic regulation of the system.

Key words: agroecological productive system, sustainability, trophic network.

Resumen

La biodiversidad es crucial en los agroecosistemas, puesto que los hace más eficientes, fuertes, productivos y resilientes. El objetivo fue determinar y comparar la biodiversidad presente en dos sistemas productivos, uno agroecológico y otro industrial en el INTA Barrow (Buenos Aires, Argentina), en los años 2018 y 2019. Se realizaron muestreos de: mamíferos, aves, artrópodos y vegetación espontánea. Se determinaron varios indicadores, abundancia, densidad, riqueza, dominancia, diversidad y equitatividad para cada grupo de estudio. El sistema agroecológico presentó mayor densidad de aves y mamíferos, riqueza de artrópodos y de vegetación espontánea respecto del sistema industrial. La mayor diversificación agrícola en la producción agroecológica evidenció una estructuración más compleja del paisaje, a través del aumento de la riqueza de vegetación espontánea y fauna benéfica que incrementarían el potencial de regulación biótica del sistema.

Palabras-clave: producción agroecológica, interacciones ecológicas, sustentabilidad.

Resumo

A biodiversidade é crucial nos agroecossistemas, pois os torna mais eficientes, fortes, produtivos e resilientes. O objetivo foi determinar e comparar a biodiversidade presente em dois sistemas produtivos, um agroecológico e outro industrial no INTA Barrow (Buenos Aires, Argentina), nos anos de 2018 e 2019. A amostragem foi realizada de: mamíferos, aves, artrópodes e vegetação espontânea. Vários indicadores, abundância, densidade, riqueza, dominância, diversidade e uniformidade foram determinados para cada grupo de estudo. O sistema agroecológico apresentou maior densidade de aves e mamíferos, riqueza de artrópodes e vegetação espontânea em relação ao sistema industrial. A maior diversificação agrícola na produção agroecológica evidenciou uma estruturação mais complexa da paisagem, por meio do aumento da riqueza da vegetação espontânea e fauna benéfica que aumentariam o potencial de regulação biótica do sistema.

Palavras-chave: produção agroecológica, interações ecológicas, sustentabilidade.

Short title: Sustainability evaluation in agrarian ecosystems

Introduction

The role of biodiversity in agroecosystems has been revalued in recent years due to the ecosystem services it provides such as nutrient cycling, biotic regulation, pest control, pollination, and others. These ecosystem services derive from the ecological processes of ecosystems, and they are closely related to biodiversity (Daily 1997; Díaz *et al*. 2007). Ecological interactions are fundamental in ecological pest management, and these interactions form networks. Species are related in intricate networks of interaction that maintain biodiversity and the stability of habitats. The type of interactions, being positive, neutral or negative, and the coexistence of them are key for management in agroecosystems because the biodiversity is crucial, as it makes them more efficient, stronger, productive and resilient (Griffon and Hernandez 2019). Interaction networks constitute a very useful tool for the conservation or rehabilitation of the benefits provided by the species and their interactions (Herrera *et al*. 2019). Regardless of the agricultural production approach, agricultural practices always imply a certain level of simplification of the ecosystem by reducing its original biodiversity. Conventional agriculture emphasizes the use of external inputs instead of ecosystem services, as well as genetic and specific uniformity at the level of the patch and even of establishment, which translates into landscape homogeneity (Sarandón 2002, Sarandón and Flores 2014b). However, with the conventional agriculture approach, intentional integration of beneficial biodiversity in industrialized agricultural systems can be seen as an impediment for production efficiency in competing for land and resources (Foley *et al*. 2005). On the other hand, an agroecological approach emphasizes the maintenance of an adequate biodiversity to maximize biological interactions, synergies and the biomass and nutrient cycle to ensure the sustainability of vital natural resources such as soil and water (Iermanó and Sarandón 2010, Paleologos and Sarandón 2014). The agroecological approach proposes that increasing agricultural biodiversity promotes an increased number of trophic interactions of the ecological community, which in turn promotes the stability of the whole system (Altieri and Nicholls 2000, 2007). Although each species contributes to the functioning of ecosystems, the nature and magnitude of their individual contributions vary considerably depending on the specific ecosystem or process. The total set of characters as well as their abundance is one of the main determinants of ecosystem functioning and existing ecological processes that result in ecosystem services (Chapin *et al*. 2000, Díaz *et al*. 2006).

Functional biodiversity is the biodiversity that determines the functionality of the ecosystem, and it is responsible for the occurrence of various individual and systemic ecological processes (Sarandon and Flores 2014 a,b). A functional group can be defined as a set of species that play a role or an equivalent ecological role, if they have similar responses to the environment and similar effects on the main ecosystem processes (Díaz *et al*. 2002; Córdova-Tapia and Zambrano, 2015). The diversity of interactions has, in principle, two components: richness and equity. In this case, richness represents the number of different types of direct ecological (trophic) interactions in the network, while equity shows how homogeneously the different types of interactions are represented (Griffon and Rodriguez 2017).

There are several ecological roles or functions: autotrophs or producers, primary consumers or herbivores, secondary consumers or carnivores, and decomposers or detritivores (Dubrovsky Berensztein 2014). The ultimate aim is to have all the functional groups represented or those that most interest us for our objectives instead of merely high richness (Iermanó *et al*. 2014). The components of agroecosystems are linked in different degrees, and this determines the degree of complexity of the system and the fulfillment of ecological functions. When diversity increases, opportunities for beneficial coexistence and interference among species increase, improving the sustainability of the ecosystem. Diversified systems favor complex food chains involving more potential connections and interactions among their members, as well as many alternative pathways for the flow of energy and matter. Thus, a more complex community is more stable (Altieri and Nicholls 2000, Zaccagnini *et al*. 2014).

The Pampas Ecoregion is an essential ecosystem of grasslands in Argentina. It expands to about 540,000 km^2, but at the same time, it is highly transformed by agricultural production. In this region, landscape homogenization and decrease in the typical pampa's grasslands biodiversity took place in the 1880s (Viglizzo 2008). This process over marginal areas and livestock fields in the Pampas grasslands of Argentina continues to transform the region. It is especially important in those subregions that had formerly been less affected by this process, such as the depressed Pampa and the Southern Pampa. Currently, the capacity to provide ecosystem services and sustain biodiversity is compromised in both these areas. This study focuses on the Southern Pampa subregion. In this context, our aim is to determine and compare the agrobiodiversity, other ecological indices and related trophic interactions of the communities of arthropods, birds, mammals and spontaneous vegetation of crops under two productive approaches: agroecological (AE) and industrial (IND) during two consecutive years (2018 and 2019). We hypothesize that the greater biodiversity in the agroecological production will be related to a greater richness of functional interactions manifesting more cohesion between the components of the system. In addition, the agroecological production will have more closed cycles in the system.

Materials and Methods

Study area

This research was conducted in Tres Arroyos Country (38°47'S, 60°06'W), a typical wheat production region in the southern Pampas Ecoregion, Argentina. The region's climate is temperate, influenced by its proximity to the ocean. The average annual temperature is 15°C, with maximum averages of 21°C and minimum averages of 9°C. Annual rainfall is close to 800mm, distributed throughout the year. The prevailing winds have N and NW orientation (Villamil and Martinez 2014). The relief is a slightly undulating plain, with an average height close to 100masl. Tres Arroyos is located within the inter-mountain portion of the Austral District of the Pampean Phytogeographic Province, and a subdivision of Espinal (Cabrera and Zardini 1978). As a consequence of the expansion of agricultural and livestock activities, there are almost no samples of native vegetation left. The landscape has been profoundly transformed by the action of plowing, cattle raising, civil constructions, and urbanized areas. This is a maximum of 500 different plant species from 80 vascular plants families that grow spontaneously in the district of Tres Arroyos (Buenos Aires, Argentina, Villamil and Martinez 2014).

Two farms were selected: one farm with an agroecological production (AE) approach that spans 9 ha and has been active for the last ten years and includes the following species: W-RC: Agroecological wheat (*Triticum* sp.) and Red clover (*Trifolium pretense*) and O-V: oat (*Avena sativa*) and vetch (*Vicia* sp.). And the other farm was under an industrial productive (IND, 20 ha); W: Industrial wheat (*Triticum* sp.), both in Chacra Experimental Integrada Barrow (MDA-INTA; N-38.3217361889837, W-60.25108873861896, Tres Arroyos, Buenos Aires, Argentina). Fields are managed commercially and were selected because they are typical examples for the area in terms of their productive approach. The samplings were carried out during the Spring of 2018 and 2019 (October and November).

Mammals sampling

We sampled micro-mammals in 2 transects per site, these separated 50 m from each other. At each transect we set 25 trapping stations each one 20 m apart, the traps used were Sherman and Tomahawk (50 traps per site, Feinsinger 2003). Each trapping session lasted three consecutive nights at each site. We used the capture-mark-recapture method. Signs of presence of medium and large mammals were recorded in two transects of 200 x 10 m per site (Feinsinger 2003). This included animals seen or heard, traces such as feces, footprints or caves, using field guides for identification (Simonetti and Huareco 1999; Parera 2011; Feinsinger 2003; Abba *et al*. 2005, 2007; Angelo *et al*. 2008, Taraborelli *et al*. 2009). The recorded species were divided into different trophic network, such as herbivorous, granivores, insectivorous, omnivore, carnivorous or nectarivorous (Gómez Villafañe *et al*. 2005; Parera 2011). The mammals samplings were carried out during the Spring of 2018 and 2019 (October and November).

Bird sampling

We established 50 m radius point counts, 4 points per site. At each point, we recorded abundance and species richness for 10 minute intervals. There were three counting points per site with random distribution. We used 10x50 binoculars (Bushnell) and a birdscope (Bushnell). Each point was georeferenced. The bird samplings were carried out during the Spring of 2018 and 2019 (October and November). Bird observation is carried out during dawn. For bird taxonomy and systematics, we consulted Narosky and Yzurieta (2003). The recorded species were divided into different trophic guilds, such as herbivorous, granivores, insectivorous, omnivore, carnivorous or nectarivorous (Narosky and Yzurieta 2003, app Aves Argentinas 2019, López Lanús 2020, Web Birds of the World).

Arthropod sampling

Pitfall traps were used for sampling ground-dweller epigeal arthropods. At the Agroecological and Industrial sites, we installed a total of eight 1000 ml capacity pitfall traps (plastic jar, diameter = 11 cm, height = 10 cm) filled with 300 ml of 5% formalin solution (Pekár 2002) and detergent (~1 ml). At each study site, four equidistant traps were placed 10 m from each other. Traps remained in the field for seven consecutive days but the frequency of checking pitfalls was one per day to verify there are not small mammals trapped that can die there (Lietti *et al*. 2008). The collected samples were transported to the laboratory, filtered and cleaned of debris and inorganic material and examined by stereomicroscope. The arthropod samplings were carried out during the Spring of 2018 and 2019 (October and November).

Morphological characteristics were used for arthropod taxonomy identification (Molina 2008a; b, 2010, 2011a; b). Because of the high abundance of Formicidae and Collembola, we only considered presence/absence records for practical purposes.

The taxonomic groups that could not be identified in the laboratory of the Chacra Experimental Integrada Barrow (INTA-MAIBA, for example Diptera) were sent to the Entomology Laboratory of the IADIZA-CCT Mendoza, CONICET to be examined by specialists. The recorded species were divided into different trophic guilds, such as herbivorous, granivores, insectivorous, omnivore, carnivorous or nectarivorous (Molina 2008a; b, 2010, 2011a; b). The results of arthropods were only used for the analysis of trophic interactions graph, establishing their interrelations (See 5. Indexes).

Vegetation sampling

For the sampling of spontaneous vegetation, each lot was covered by foot following a zig-zag pattern and the total density (plant/m^2) was determined in 5 sampling units and by species in an area of 0.25 m^2 (Braun Blanquet 1979) for the years 2018 and 2019. The presence and abundance (cover) of species per plot (census) were estimated in percentage terms (Knapp 1984; Merle Farinos and Ferriol Molina 2012; Alcaraz Ariza 2013; Carrasco *et al*. 2015). The position of the 0.25 m^2 areas were determined using a Global Positioning System (Gps Garmin Legen Etrex). The vegetation samplings were carried out during the Spring of 2018 and 2019 (October and November).

Species identification was made following Cabrera and Zardini (1978), Dimitri (1978), Lamberto *et al*. (1997), Zuloaga *et al*. (2008) and Villamil and Martínez (2014). The results of vegetation were only used for the analysis of trophic interactions graph, establishing their interrelations.

Indexes

We estimated (or determined) abundance, density (N/ha) in birds, mammals and vegetation, species richness (S), defined as the number of species/taxon; the Simpson Dominance Index (*D*) whose mathematical expression is: $D = \sum pi2$, where pi represents a relative relationship between "ni" (number of individuals of the species) and N (total individuals sampled), the Shannon diversity index (Magurran 1988) using the formula: $H = - \sum [(ni / N) * \ln (ni / N)]$. The standardized Shannon index H´st= H/H´max (the ratio between the observed value H and the maximum value of the H´max index for a system of equal number of species), and evenness (E) from the calculation= H'/ ln S. For spontaneous vegetation, abundance of each species was also determined as the relationship between the number of individuals of each species and the total number of individuals sampled and the richness of botanical families. The data from both years were pooled for the ANOVA.

For statistical analysis, an analysis of variance (ANOVA) was performed and Fisher's least significant difference test was used for the separation of means ($p<0.05$). Statistical analyzes were performed using the Infostat® (statistical software, FCA, Universidad Nacional de Córdoba, Argentina; Di Rienzo *et al*. 2020).

The recorded species were divided into different trophic guilds, such as herbivorous, granivores, insectivorous, omnivore, carnivorous or nectarivorous to build trophic network and calculate ecological indices and Index of agroecological diversity (I Agro). Griffon 2008a proposed a new index to measure agrobiodiversity and compared an industrial field and in another agroecological field. This index allows the evaluation of the system as a whole. In this index, besides of measuring the richness and abundance of the elements of the system, it is also taken into account their interaction. This allows the evaluation of functional attributes of the agrobiodiversity.

Each study site was considered as a complete ecosystem and was represented in a graph, establishing the components of agrobiodiversity and their interrelations. Each registered bird or mammal species was represented as an element of the system. Trophic groups of arthropods and vegetation strata were represented as nodes, and the nodes were related according to their main diet (Griffon and Rodríguez 2017). The nodes represented populations of species and the links are the direct trophic interactions (Griffon and Rodríguez 2017).

The three measures necessary to obtain the I Agro of each study site were calculated: the standardized Shannon index (H´St) (Magurran 1988); the density of the links (D) measured as the ratio of the observed number of links to the theoretical maximum number of links in the system (Costa *et al*. 2007); and the clustering coefficient (C) that relates the presence of short loops within the graph (Costa *et al*. 2007) allows to infer the redundancy of the system and its functional structure. These measurements were calculated with the statistical software R (Team 2013) for the analysis of networks and data in Pajek format (Griffon 2008a). The Agro I index allows evaluating the attributes of agrobiodiversity, which are impossible to study through the use of classical ecological indices (Griffon 2008a). It is also consistent with the theoretical framework of agroecology and the index structure is extremely simple, I Agro = H´St + D + C. Since all components of the index are standardized (their maximum value is 1), the maximum value of the Agro I index is 3 (Griffon 2008a; Griffon and Rodríguez 2017).

Results

A highest number of birds and mammals, species richness and density (D, individuals/ha) were found in agroecological productive system ($p= 0.0154$; $F= 5.59$; gl= 14; $p= 0.0027$; $F= 12.8$; gl= 14; $p= 0.0002$; $F= 15.44$; gl= 14). The Dominance Index (Dm) and the standardized Shannon Index (H´st) did not show differences between the plots with different managements (D: $p= 0.641$; $F= 0.46$; gl= 14; H´st: $p= 0.0805$; $F= 2.99$, gl= 14) (Table 1).

Regarding the abundance of arthropods, there were no differences between systems nor between crops within each system in either of the two years evaluated. Species richness was higher ($p<0.05$) in agroecological productive system, without differentiating between the two crops in 2019 ($p<0.05$). The greatest density was obtained by the arthropod community of the wheat with industrial management in 2019 ($p<0.05$). The greatest equitability was presented in O+V with agroecological management AE in 2019, that is to say that the arthropod community was more equitable (Table 1).

The density of spontaneous species was higher in agroecological management in 2019 ($p=0.0416$). It is important to clarify that in 2018 there were no spontaneous records in the sampling of the IND system, probably due to the performance of chemical control procedures close to the survey sites. This did not allow the calculation of the ecological indices for this year. Species richness and family richness were higher in the agroecological system compared to the industrial for both years ($p=0.0082$ and 0.009). Among the surveyed species we recorded: *Polygonum convolvulus*, *Lolium* spp., *Setaria* spp., *Euphorbia dentata*; *Chenopodium album*, *Raphanus sativus*, *Cirsium vulgare*, *Ammi majus* and *Anagallis arvensis*. Eighty percent of these species were not believed to be present or were rarely found in the industrial system for 2019. Setaria spp. was the most abundant species with values greater than 80% in both systems and years of study. In 2019, the number of botanical families presented a tendency to be higher in the agroecological system, where a greater number and frequency of appearance of those botanical families were cited favoring the

Table 1. Ecological indices for birds and mammals, arthropod fauna and spontaneous vegetation in wheat, wheat and red clover, oats and vetch in 2018 and 2019 under two productive approaches in argentine pampeana region.

Taxa	Management		Crops	R		N	D	Dm	Hst
Birds and mammals	2018	AE	W+RC	13 b		72 b	16.00 b	0.68 a	0.792 a
		IND	W	9 a		62 a	3.10 a	0.66 a	0.886 a
	2019	AE	W+RC	12 b		145 c	32.22 c	0.49 a	0.661 a
			O+V	12 b		176 c	39.11 c	0.49 a	0.609 a
		IND	W	9 a		48 a	2.40 a	0.52 a	0.799 a
				R		**N**	**D**	**E**	**H**
Epigeal arthropods	2018	AE	W+RC	15.50 b		178 b	0.34 ab	0.48 b	1.32 b
		IND	W	12.80 a		205 b	0.43 b	0.42 b	1.07 a
	2019	AE	W+RC	17.68 c		64 a	0.20 a	0.49 b	1.40 b
			O+V	17.75 c		86 a	0.21 a	0.62 c	1.77 c
		IND	W	11.67 a		81 a	0.71 c	0.25 a	0.63 a
				R	**Rf**	**D**	**Dm**	**E**	**H**
Vegetation	2018	AE	W+RC	4 b	3 b	388 b	0.74	0.38	0.50
		IND	W	0 a	0 a	0 a	-	-	-
	2019	AE	W+RC	5 b	5 b	2565 d	0.81 a	0.24 a	0.39 a
		IND	W	3 a	3 b	913 c	0.76 a	0.32 a	0.44 a

Different letters indicate significant differences ($p<0.05$) between systems for the same variable and year of determination. (R: Species richness, N: total number of individuals, D: density (D, N/ha, plants/m2), Dominance (Dm), H: Shannon specific diversity, H'st: standardized Shannon index, E:equity, Rf: family richness, AE: Agroecological, IND: Industrial, W: wheat , W + RC: wheat + red clover, O + V: oats + vetch).

presence of natural controllers in the system: Asteraceae, Apiaceae, Fabaceae.

In the graphics (Figure 1) we can see that the highest link density was registered in agroecological management, with greater number of nodes; among mammals, birds, types of vegetation and groups of arthropods. Also, the clustering coefficient was higher in agroecological management in 2019, where occurred >54% where occurred >54% of the possible short loops within the graph (the clustering coefficient, C). This percentage provides information on the functional structure of the system, and this allows to infer the redundancy of the system and its functional structure. This percentage provides information on the functional structure of the system. In addition, the highest I Agro also occurred in agroecological system in 2019 (Table 2).

Discussion

Our results show that agricultural diversification creates a more complex landscape structure at multiple scales. Parameters like greater number and density of birds/mammals in the agroecological production (AE) increase the beneficial fauna in these ecosystems. The greatest equitability was presented in agroecological management in 2019, that is to say that the arthropod community was more equitable and therefore, there would not be a dominant species enhancing a more stable system (Magurran 1988). In the agricultural establishments, agriculture generated a simplification of the plant communities within the productive lots by moving from polyculture to monoculture, as well as by intensifying the control of weeds and pest arthropods through the increasingly intensive use of agrochemicals

Table 2. Agroecological index for the two productive approaches in wheat, wheat and red clover, oats and vetch in 2018 and 2019 in argentine pampeana region.

Management		Crops	H'st	D	C	I Agro
2018	AE	W+RC	0.549 b	0.941 c	0.503 a	1.992 b
	IND	W	0.513 ab	0.897 b	0.504 a	1.914 ab
2019	AE	W+RC	0.721 c	0.984 c	0.575 b	2.281 c
		O+V	0.753 c	0.913 c	0.541 b	2.210 c
	IND	W	0.472 a	0.752 a	0.530 a	1.754 a

Different letters indicate significant differences ($p<0.05$) between systems for the same variable and year of determination. (H´St: standardized Shannon index, D: the density of the links, C: the clustering coefficient, and I Agro: the Agroecological index, AE: Agroecological, IND: Industrial, W: wheat , W + RC: wheat + red clover, O + V: oats + vetch).

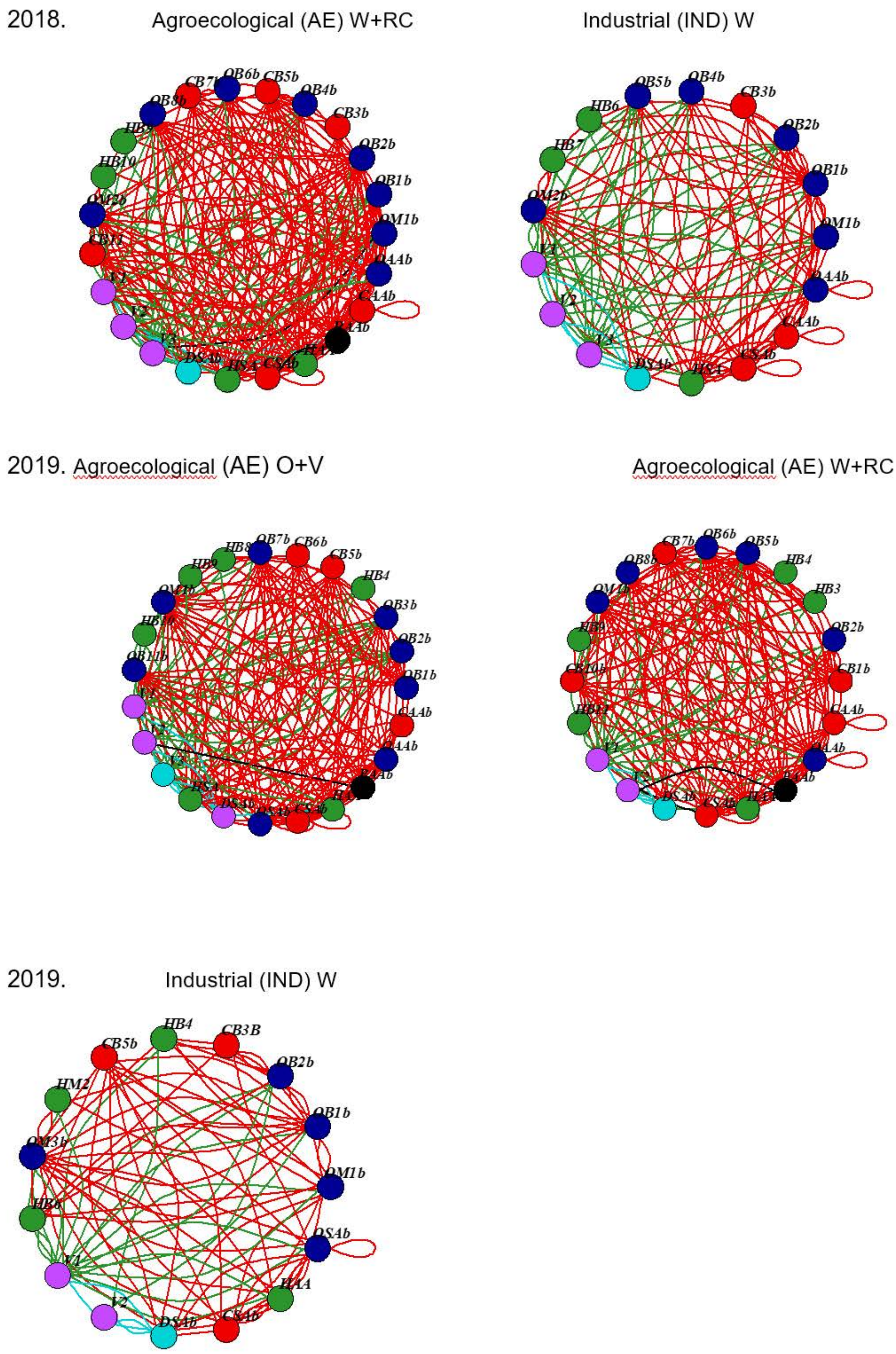

Figure 1. AR Graph´s represents the ecological networks of each study site in argentine pampeana region. The nodes represent populations of species and links are the direct trophic interactions. Agroecological (AE) and Industrial (IND). In different crops: wheat (W), wheat + red clover (W+RC), oats + vetch (O+V) in 2018 and 2019. Nodes and links (Colours) 1) H= Herbivore (forestgreen), O= Omnivore (blue4), C= Carnivore (red2), P= Pollinator (black), D= Detritivore (darkturquoise), V=vegetation (darkorchid1). Other letters: M= Mammal, B= Birds, A= Arthropods (SA: soil arthropods, AA: air arthropods); b= beneficial species.

(Benton *et al*. 2003; Hendrickx *et al*. 2007; Bilenca *et al*. 2009). This abusive use of pesticides generates the resistance of a part of pests and weeds (Krupke *et al*. 2012; Egan *et al*. 2014). In this way, the systems became increasingly vulnerable, because natural enemies are eliminated and pests appear that are increasingly difficult to control with the current practices (Donald *et al*. 2001, López 2016). In this type of farming system most species are related directly to one (the monoculture) by a victim-exploiter relationship (i.e., predation, parasitism, parasitoidism or herbivory), where the monoculture species (the crop) typically plays the role of the victim. So, the system is represented by a star-like architecture (i.e., many nodes connected to a central hub) with the monoculture in the center (Griffon and Torres-Alruiz 2008), which is a structure that favors the occurrence of pests and crops loss (Griffon and Hernández 2019; Griffon and Rodríguez 2017).

Spontaneous plant species represent the basis of the general diversity of agroecosystems because they are a source of food and habitat for organisms of other trophic levels, such as beneficial insects that reduce crop pests, insectivorous and pollinators (Albrecht, 2003; Marshall *et al*., 2003; Herrera *et al*., 2017). Likewise, the presence of spontaneous vegetation together with the greater specific richness and botanical families' richness in the agroecological system reveals the potential effect of these species on the biotic regulation of the system. And its contribution leads to the increase in plant diversity vegetation. On the contrary, the scarce or non-existent presence of spontaneous vegetation in the industrial system, with low species richness, reflects a decrease in habitat and refuge or feeding sites for predators and parasitoids arthropods. This was evidenced by the lower richness of these arthropods in the industrial system in our study. Therefore, greater plant heterogeneity leads to a better natural regulation of the wild populations of the agroecosystem. In this way the system can regulate itself with no population peaks for certain species reflecting the importance of maintaining high biodiversity ecosystem in time and space (Knapp 1984, Sarandón 2002, Sarandón and Flores 2014b).

The highest density of the links and the clustering coefficient indexes across species (mammals, birds, type of vegetation and arthropod groups) suggest that the agroecological system generates a greater degree of cohesion and integration between the components of the system in relation to the other situations studied. These values are associated with systems that self-regulate and have closed trophic cycles. Diversity plays a significant role in maintaining the resilience of ecosystems (Salgado-Negret and Paz 2015), giving it the ability to adapt to disturbances, reorganize and sustain itself over time (Calvente 2007). There are different trophic groups and a large number of species within them (Perrings 2006; López 2016). For example, pollinators fulfill a specific function and can be represented by bees, bats, birds, among others (Folke *et al*. 2002). Therefore, the characters as the abundance in a community, is one of the main determinants of ecosystem functioning (Chapin *et al*. 2000; Díaz *et al*. 2006).

Ecological networks allow the integration of all relationships between the components of biodiversity, in order to observe how changes in one could affect the other, modifying the multiple emerging functions of the ecosystem. In this way, they constitute powerful tools when it comes to working with complex systems, which entities interact through various processes, leading to different responses (Dubrovsky Berensztein 2014). An agroecosystem with a high number of functional groups and a diversity of taxa within each one, will have a broader set of responses to changes in the environment, giving it greater long-term stability. This ability to absorb disturbances while undergoing changes and basically maintaining the same structure, functioning and self-regulation mechanisms, demonstrates the degree of reliance that an ecosystem has.

The Agroecological index, apart from measuring the richness and abundance of the elements in the system, it also takes into account the interactions within it. This allows the evaluation of functional attributes of the agrobiodiversity. The highest I Agro also occurred in agroecological system in 2019, the year with more rain of the two. This result is due to the fact that in the agroecological system there was a greater density of interactions between the components, and the higher grouping coefficient allows us to infer that the system has a strong functional structure and a better capacity to self-regulate and be stable (homeostasis). The I Agro index allows the evaluation of the system as a whole and is a useful tool to carry out systemic diagnoses of productive units (Griffon 2008a, b; Griffon and Rodríguez 2017).

Ecological networks allow incorporating the relationships between the components of biodiversity, to observe how changes in some could affect others, modifying the multiple emerging functions of the ecosystem (Dubrovsky Berensztein 2014). An agroecosystem with a high number of functional groups and a diversity of taxa within each group, will have a broader set of responses to a change in the environment, giving it greater long-term stability. This ability to absorb disturbances and reorganize itself while it is undergoing changes or after having undergone them, allows the system to maintain structure, functioning and self-regulation mechanisms. The resilience of this ecosystem is guaranteed to a large extent by the presence of various functional groups and the interactions between them (Dubrovsky Berensztein 2014; Griffon and Hernandez 2019).

Conclusions

Based on the results obtained, it is concluded that it is necessary to study biodiversity to get the Agroecological index allows the evaluation of the system as a whole. In this index, not only the richness and abundance of plant and animal species but also include the relationships that occur between them. This allows the evaluation of functional attributes of the agrobiodiversity. Important types of interaction between the components of an agroecosystem are the non-linear trophic relationships that determine the stability of the populations present. The agroecological system presented higher density of birds and mammals, richness of arthropods and spontaneous species compared to the industrial system. The greater agricultural diversification in the agroecological system evidenced a more complex landscape structure, through the increase in the richness of spontaneous species and beneficial fauna that would increase the potential for biotic regulation of the system. The use of simple and practical indicators is vital to provide technicians, producers and politicians with reliable and understandable information about the impacts and costs of incorporating different productive approaches.

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