Scientific Paper

Determination of biodiversity and evolution of complexity in La Palma farm, Perico municipality

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Abstract

Objective: To characterize biodiversity and determine the evolution of complexity in La Palma farm, in the El Roque town, Perico municipality, Matanzas, Cuba.

Materials and Methods: The evolution of animal and plant biodiversity was quantified in the farm. Margalef and Shannon indexes (H´) and the degree of complexity of biodiversity, which considers five components: noxious, functional, introduced functional, auxiliary and productive, were determined during three years (2017-2019).

Results: The inventory recorded several species of animals and plants in the farm. The main function of the animals was to produce milk and meat, animal traction and transport, mainly horses. Chicken and sheep are used for family food and dogs are used as pets. As for the plant component, the presence of species for human and animal feeding was analyzed, distributed in areas of multipurpose trees (fruit trees, timber and feed), staple crops and forage. According to the evaluation scale, the Shannon index (1,81-2,57), as well as the Margalef index (2,22-2,82), showed a value in the range considered as moderate. Regarding the complexity analysis, during 2017 and 2018, the farm was classified as not very complex, and evolved to moderately complex in 2019.

Conclusions: The farm showed in the years of study increased biodiversity, of plants as well as animals. The evolution of the complexity of the farm, from low to moderately complex, according to the scale used, facilitated the formation of a strategic plan for the farmer to follow and be able to reverse the situation of his farm until it could be taken to the maximum scale (highly complex).

Keywords: animals, diversification, plants, sustainability

Introduction

Biodiversity in an agroecosystem is made up of all the existing species that interact in it. In recent years, scientists have begun to ascribe higher importance to the role played by biodiversity in the functioning of agricultural systems, considering that it is precisely the fundamental principle of sustainable agriculture (Vergara-Ruiz, 2017).

In Cuba, many farms have implemented diversified, integrated, sustainable agroecosystems managed with local resources, with alternative energy sources and minimal use of inputs (Funes-Aguilar, 2016), which has become a priority in recent years. That is why the study of biodiverse systems and their potential is identified as a necessary aspect for sustainable agriculture (Nova, 2016). The evaluation of complexity will serve as a learning element for farmers who acquire knowledge about how to continue improving the social, economic and environmental sustainability of their production systems.

The objective of this study was to characterize the biodiversity and determine the transition of complexity in La Palma farm, El Roque village, Perico municipality, Matanzas, Cuba.

Materials and Methods

Location. The research was conducted in the La Palma farm, belonging to the Ramón Rodríguez Milián Credit and Service Cooperative (CCS, for its initials in Spanish), in the Perico municipality, Matanzas province. This farm has a total of 26,84 ha.

The farm was selected for the study because it is in the transition to a sustainable system, as a sample of confidence of the projects and programs of local agricultural innovation (PIAL, for its initials in Spanish) and the environmental bases for food sovereignty (BASAL, for its initials in Spanish), in Matanzas. In addition, it was one of the farms selected by the Municipal Delegation of Agriculture as a school farm for the last project.

The farm's history, length of operation, and the farmer's innovative character and leadership were

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taken into consideration. The evaluation was conducted over three years (2017-2019).

Determinations. The number of species and individuals for each species was quantified during the three years (in each tour of the farm, every two months) and they were characterized according to their purpose. The indexes used to evaluate biodiversity were Margalef's (MI) (species richness) [MI = (S-1)/LnN, where S = total number of species and N= total number of individuals of all species] and Shannon's (H) (species diversity) [H= ∑ pi ln pi), pi = proportional abundance of species i, i.e., the number of individuals of species i divided by the total number of individuals in the sample], according to the recommendations made by Moreno (2001), and its calculation was performed using the program Diversity species & richness 3.02 (Henderson and Seaby, 2002).

Biodiversity identification was carried out using the ITIS (Integrated Taxonomic Information System) web page.

The determination of the degree of complexity of biodiversity components was carried out according to the methodology for the rapid characterization of biodiversity in farms from agroecological pest management, proposed by Vázquez-Moreno and Matienzo-Brito (2010), which considers five components of biodiversity: 1) the productive biodiversity (PB) which is the introduced or native biota, which is cultivated or raised for economic purposes (plants and animals, agrobiodiversity); 2) the noxious biodiversity (NB) comprising organisms that affect plants and animals of economic interest (agricultural pests); 3) the functional introduced biodiversity (FIB), which includes organisms that are massively reproduced and are introduced into the system through inoculative or augmentative releases or applications (entomophagous arthropods, entomopathogenic nematodes, entomopathogenic microorganisms, antagonists, biofertilizers, organic fertilizers and mycorrhizae); 4) the functional biodiversity (FB) which is related to pest bioregulators (organisms that naturally regulate the populations of phytophages, phytoparasites and phytopathogens) and 5) the auxiliary (AB) which is the biota that naturally inhabits agricultural systems and indirectly contributes to the rest of the biodiversity. This includes plants that grow wild or are managed, but not primarily for productive purposes, as well as animals used in agricultural work.

For each component, different indicators were evaluated, to which, according to the field value they acquired, either absolute or percentage, degrees of complexity were attributed, according to the scale shown in table 1. Subsequently, each degree of the scale was multiplied by the total number of indicators or components that possessed it, and at the end all the values resulting from this multiplication were added up. The degree of complexity of each component (i.e., productive, harmful, auxiliary, functional introduced and functional biodiversity) was obtained by dividing the value resulting from the sum of the multiplication of each indicator by the value of the multiplication of the total number of components by the number of grades of the scale (N=5). The degree of complexity of the farm was obtained by dividing the value resulting from the sum of the multiplication of each indicator-grade by the value of the multiplication of the total number of components (n=48) by the number of degrees on the scale (N=5) and, finally, by multiplying by one hundred to obtain the percentage value.

Results and Discussion

Biodiversity. The inventory reported the presence of several animal and plant species in the farm. The main function of the animals was to produce milk and meat, which are the most important productive items. In addition to providing a source of animal protein for consumption, they have other uses, such as animal draught and transportation, mainly horses.

Table 1. Scale used to classify the complexity of each indicator and component of biodiversity, as well as of the farm.

Degree of complexity of the system	Expression of the results[¥]		Name of the degree of complexity of the farm
	Absolute value	%	
0	0	0	Simplified
1	1-3	1-25	Little complex
2	4-6	26-50	Moderately complex
3	7-10	51-75	Complex
4	More than 10	More than 75	Highly complex

[¥]Fractions above 0,5 of the final value are considered in the following value (Example: 3,8 is 4)

Chicken and sheep are used in family feeding, and dogs are used as guards and pets.

According to Ramírez-Iglesias *et al*. (2020), the presence of animals in agroecosystems is beneficial because of their contribution to nutrient recycling, soil conservation and the capacity to transform phytomass into sources of food and goods for human and animal use. Table 2 shows the composition of the animals present in the farm and the function they perform.

Ramírez-Iglesias *et al*. (2020) also state that the presence of these different animal species in agroecosystems is important because of their direct impact on agriculture. Their main function is related to their contribution to nutrient recycling and their capacity to transform phytomass into a source of food and goods for human use. They also constitute a source of income, as economic sustenance for the system.

Regarding the plant component, the presence of species destined for human and animal feeding was analyzed. They were distributed in forage areas, grazing, multipurpose trees (fruit trees, timber, animal feed) and staple crops (table 3).

As can be seen, the main crops are: *Phaseolus vulgaris* L., *Zea mays* L., *Manihot esculenta* Crantz and *Solanum lycopersicum* L. With these productions, family self-sufficiency is supplied, and the plan of delivery to the productive base is fulfilled.

Multipurpose trees provide shade, fodder and fruit, legumes fix atmospheric nitrogen, recycle nutrients, reduce the cost of fencing, conserve and improve the soil and herbaceous vegetation, protect the water potential of the site and serve as habitat for many species of animals, making them true jewels in a diversified system, according to Baldini (2020).

It is important to value the influence of trees as environmental enhancers and the growing importance ascribed to the forest resource, among the strategies and actions aimed at environmental protection, especially in the agricultural and livestock sphere.

The rescue, planting and establishment of these tree species with different economic interests, such as food and timber, allowed to conserve and return to the agroecosystem those that were previously present, but had been reduced by indiscriminate felling. This was corroborated due to the intervention of a worker (more than 80 years old), who knew accurately the place where the farm is now located.

The presence of these species coincides with the report by Milián-García *et al*. (2018), who stated that *M. indica*, *P. americana* and *P. guajava* species were the most representative in a study conducted on a farm in Perico, Matanzas. These species were also mentioned by Lezcano-Freires *et al*. (2020), who determined biodiversity in a farm in the Colón municipality, Matanzas, Cuba.

Trees benefit the ecosystem, as they improve the environment and the physical, chemical and biological quality of soils. In addition, they increase the organic matter content, can be used as living fences, provide shade, produce fruit, recycle nutrients, lower the cost of products in the markets, protect the water potential of the site, serve as habitat for wildlife and provide goods and services beneficial to the human population (Pozo, 2019; Amaya-Romero and Gutiérrez-Castro, 2020).

A positive environmental aspect, which was recorded with the progressive promotion of these multipurpose tree species, was the appearance of avifauna species, among which we can mention the common ground dove [*Columbina passerina* (Linnaeus, 1758)], eastern meadowlark [*Sturnella magna* (Linnaeus, (Linnaeus, 1758)], plain pigeon [*Patagioenas inornata* (Linnaeus, 1758)], grassquits

Table 2. Number of animals present in the farm and their functions.

Species	Quantity			Function
	2017	2018	2019	
Chicken [*Gallus gallus domesticus* (Linnaeus, 1758)]	7	10	7	Egg production and food
Horses (*Equus caballus* Linnaeus, 1758)	3	5	12	Transportation
Cattle (*Bos taurus* Linnaeus, 1758)	63	102	158	Milk and beef production, animal draught
Pigs (*Sus scrofa scrofa* Linnaeus, 1758)	10	16	22	Food
Sheep (*Ovis aries orientalis* Gmelin, 1774)	8	10	5	Food
Dogs (*Canis lupus familiaris* Linnaeus, 1758)	0	1	3	Guards and pets

Table 3. Number of species of the plant component present in the agroecosystem.

Species	2017	2018	2019
Mangifera indica L.	5	25	30
Persea americana Mill.	20	70	90
Psidium guajava L.	4	4	10
Citrus cinensis L.	3	3	7
Citrus x limón (L.) Osbec.	2	2	5
Annona reticulata L.	2	2	5
Pouteria sapota (Jacq.)	3	4	6
Annona squamosa L.	3	3	3
Melicoccus bijugatus Jacq.	2	2	2
Spondias dulcis Parkinson.	4	15	30
Cocos nucífera L.	1	1	3
Cucumis sativus L	0	0	16 000
M. esculenta	6 000	15 000	21 000
Z. mays	22 500	31 500	45 000
P. vulgaris	300 000	390 000	450 000
S. licopersycum	300 000	400 000	406 000
Allium sativus L.	0	0	80 000
Cucurbita pepo L.	0	0	70 000
Capsicum anum L.	0	0	16 000
Daucus carota L.	0	0	12 000
Petroselinum crispum (Mill.) Fuss	0	0	34 000
Samanea saman (Jacq.) Merr.	1	3	3
Erythrina berteruana Urb.	3	3	3
Bursera simaruba (L.) Sarg.	5	10	20
Gliricidia sepium (Jacq.) Walp.	15	40	80
Moringa oleífera Lam.	5	8	10
Saccharum officinarum L.	17 000	21 000	30 000
Cenchrus purpureus (Shumach). Monrone.	20 000	20 000	10 000
Megathyrsus maximus (Jacq.) Simón & Jacobs.	0	120 000	400 000
Dichanthium annulatum (Forssk.) Stapf, *D. aristatum* (Poir.) C.E. Hubb. *Dichanthium caricosum* (L.) A. Camus, *Bothriochloa pertusa* (L.) A. Camus	1 100 000	950 000	300 000
Beta vulgaris L.	0	0	10 000
Vigna unguiculata (L.) Walp.	0	0	17 000

[*Tiaris canora* (Gmelin, 1789)], hummingbird [*Mellisuga helenae* (Linnaeus, 1758)] and kestrels [*Falco sparverius* (Linnaeus, 1758)], which according to local residents had not been seen for several years. López-Vigoa *et al.* (2017) stated that, with the increase of trees in animal husbandry systems, the presence of birds and other animal species is benefitted. Also Aguilar *et al.* (2017) reported an increase in avifauna in cattle ranching areas of Ecuador. This happened when areas began to be repopulated with multipurpose trees.

Other promoted species were *G. sepium* (matarratón or quickstick) and *S. dulcis* (June plum), mainly for the development of living fences.

According to Zamora-Pedraza and López-Acosta (2017), from an ecological point of view, living fences function as refuge areas, ecological niches and passage sites for certain organisms (plants, insects, birds and small mammals), as mentioned above.

Two species are used for forage production: *S. officinarum* and *C. purpureus*, and among the identified natural and naturalized grasses there was a predominance of the *Dichantium-Bothriochloa* complex and the SSP areas had the presence of two tree species, *Leucaena leucocephala* (Lam) de Witt and *G. sepium* and *Megathyrsus maximus* (guinea grass), as the basis grass, and the Likoni cultivar, a commercial variety adapted to tropical soil and climate conditions. All these species are among the most commonly used in animal husbandry systems (Hoek and Mena, 2019).

The staple crop species were planted in areas of self-consumption and greenhouse, both are modalities of food production systems, which contribute to improve food and nutritional security and the economy of small farmers (Anaya-Cruz, 2020).

In any study of the diversity of an agroecosystem, it is important to go beyond the typical inventories, which only provide qualitative data on the existence of species in the different types of production models. Therefore, the current trend is to quantify floristic information through sampling, with which structural indicators can be obtained, such as density, abundance, dominance, frequency, importance value index and diversity and similarity indexes, which allow to measure diversity and interpret the real conservation status of the flora of a given sector (Céspedes *et al*., 2019).

When determining the index of species diversity (Shannon) and species richness (Margalef), it was found that both increased over the years of study (table 4). This was favored by the implementation of a group of practices, such as crop rotation, crop association, intercropping, use of organic fertilization, use of living barriers, use of diversification of species, varieties and plant cultivars, recycling of crop residues, promotion of silvopastoral system areas with aquaculture and delimitation with living fences; in addition to the combination of legumes and grasses for livestock feeding and the planting of fruit and timber trees.

In relation to species diversity (Shannon index), it was found to be in the range of 1,81-2,57; according to the evaluation scale, and was therefore classified as moderate diversity. These results confirm the potential of integrated animal husbandry and agriculture systems, which are essential to face the productive limitations of tropical regions and the urgent environmental, economic and social limitations of sustainable agricultural development (Vera-Pérez, 2011). When comparing the values obtained by Blanco *et al*. (2014), it was observed that they were below (1,6 and 2,16) those of this research.

Table 4. Performance of biodiversity indexes in the farm.

Index/Year	2017	2018	2019
Shannon	1,81	1,92	2,57
Margalef	2,22	2,26	2,82

Regarding the Margalef index, it can be stated that it showed a value in the range of 2,22-2,82 for the three years of study, considered as mean value. These values are lower than those reported by Milián-García *et al*. (2018), who obtained an index of 5,03 when evaluating the biodiversity functionality of trees in a farm in agroecological transition. This index assumes that there is a relationship between the number of species and the total number of individuals.

This demonstrated the balance between the number of species present in the evaluated system and the number of individuals per species, where an accelerated increase of crops was observed. López-Hernández *et al*. (2017) determined the composition and diversity of tree species in Mexico, and obtained lower values of species richness (1,35) compared with those found in this study.

The evaluation of the indexes provides a quantitative measure. However, their ecological appraisal is difficult and often very controversial, since it depends on the objective of the study. In this research it is necessary to make other appraisals, based on the transformations achieved as part of the agroecological transition process.

The analysis of the complexity of the farm (table 5) showed that biodiversity presented a degree of low complexity (years 2017 and 2018) to moderate complexity (year 2019). This performance in the farm was due to the fact that the studied indicators for each component showed a similar result.

It is important to highlight the evolution that the farm has undergone, with discrete percentage increases in each component per year under study. In this regard, the low complexity (simplified) observed in the FB, during the three years, and in the FIB and NB, in 2017, was mainly due to the fact that the farmer did not carry out some good practices in the farm, such as the release of rustic offspring, and natural enemies, pollinator diversity, organic and foliar fertilizers, among others.

Table 5. Performance of the biodiversity components of the farm under study.

Biodiversity component	2017		2018		2019	
	%	DC	%	DC	%	DC
Productive (PB)	16,4	1	27,3	2	32,7	2
Auxiliary (AB)	24,0	1	22,0	2	36,0	2
Functional (FB)	9,0	1	12,8	2	21,8	1
Functional introduced (FIB)	15,6	1	35,5	2	40,0	2
Noxious (NB)	20,0	1	22,9	2	22,9	2
Classification of the farm regarding the biodiversity complexity degree	Little complex (16,0 %)		Little complex (23,0 %)		Moderately complex (30,0 %)	

PB: productive biodiversity, AB: auxiliary biodiversity, FB: functional biodiversity, NB: noxious biodiversity, FIB: functional introduced biodiversity, DC: degree of complexity.

This working concept evolved over time. The farmer began to apply the release of *Trichogramma speciosus* (entomophagous); of entomopathogens or biopesticides, such as *Bacillus thuringiensis* (Berliner, 1915) strain 13 and strain 24; *Lecanicillium lecanii* (Zimmerm.) and *Beauveria bassiana* (Bals.) Vuill.; in addition to the use of antagonistic organisms, such as *Trichoderma harzianum* Rifai strain, organic fertilizers, biofertilizers and mycorrhizae, which improved the condition of the above-mentioned components.

However, there were indicators, among the different components of biodiversity, which did not express their maximum potential, due to the fact that agroecological practices were not systematized, such as crop rotation and intercropping, release of natural enemies and use of organic products in larger quantities, among others. These practices were not implemented from the beginning, due to a lack of knowledge by the farmer, material resources and inputs. To eliminate these deficiencies, the farmer was trained in good practices that improve biodiversity components, including the use of bioregulators and diversification of natural enemies, among others. This led to a reduction of NB in the farm.

These results ratify the importance of biodiversity in the production system and the need to integrate the different components in the system, not only animal and plant, but also forestry, ornamental and auxiliary biodiversity. The diversification of each practice that is integrated in the system can contribute to a higher genetic and structural diversity of the productive biota (Vázquez-Moreno, 2013).

In addition, it is necessary to take into account in productive biodiversity the need to consider that all agroecosystems are dynamic and subject to different types of management. Therefore, crop arrangements in time and space change continuously, according to biological, socioeconomic and environmental factors. Such variations in the landscape determine the degree of heterogeneity characteristic of each agricultural region, which in turn conditions the type of biodiversity present (Morgado-Martínez *et al*., 2019).

Martínez-Maqueira *et al*. (2020) stated that the development of farms under agroecological conversion, where several cultivable plant species and domestic animals are integrated, allowing synergies and complementarity among species, in harmony with the environment and for the benefit of society, is an important contribution to achieving sustainable development.

In this regard, Vázquez-Moreno (2011) proposed that the greater the diversity of cultivated plants and livestock in the farm, the higher the possibility of bringing the production system closer to the characteristics of natural ecosystems and, therefore, reducing its artificiality. This diversification reduces the incidence of harmful organisms and increases their natural control, which helps to prevent them from manifesting as pests, due to the various effects of confusion, repellency and reduction of food resources.

Conclusions

The farm under study showed an increase in plant and animal biodiversity over the years. As for the evolution of the complexity of the farm, it was observed how it went from not very complex to moderately complex, according to the scale used. This allowed to create a strategic plan for the farmer to reverse the situation of his farm until it could be taken to the maximum scale (highly complex).

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Conflict of interests

The authors declare that there is no conflict of interests among them.

Authors' contribution

- Yuseika Olivera-Castro. Design and setting up of the research and advisory, data processing and paper writing.
- Néstor Núñez-García. Conformation of the research, measurement taking in the field and paper writing.
- Wendy Mercedes Ramírez-Suárez. Data processing and paper writing.

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