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Diversity of Plant Species on Farms in the Municipality of Camagüey

Yudelkis González Portelles[1], José Luis Céspedes Cansino[2] & Concepción de la Torre Rodríguez[3]

[1]ORCID https://orcid.org/0000-0001-5258-9513, The Ignacio Agramonte Loynaz University of Camaguey, Fifth-Year student, Agronomy Engineering, Camagüey, Cuba, [2]ORCID https://orcid.org/0000-0003-0541-9436, The Ignacio Agramonte Loynaz University of Camaguey, Department of Agronomy, Camagüey, Cuba, [3]ORCID https://orcid.org/0000-0002-9144-4322, The Ignacio Agramonte Loynaz University of Camaguey, Department of Agronomy, Camagüey, Cuba.

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Email: jose.cespedes@reduc.edu.cu; conchy.delatorre@reduc.edu.cu

Abstract

Context: The preservation of biodiversity integrated into agricultural practices may bring about enormous social, economic, and ecological benefits; Hence, the practices that conserve and have a sustainable use, increasing biodiversity, are necessary for farming systems to ensure food production, life quality, and the health of ecosystems.
Aim: To conduct a qualitative and quantitative evaluation of plant species diversity as an element of agroecosystem functioning.
Methods: The species found on farm fields (0.24 hectares) are shown. Accordingly, the farm areas were divided into 6 transects (80 m x 5 m each), in 16 5 x 5 m plots. The Alpha diversity indexes were calculated (the Margalef diversity index, the Pielou uniformity index, the Shannon-Wiener index), and Beta (the Jaccard index); the agroecosystem agrobiodiversity index was included as well.
Results: The Alpha diversity indexes was inclined to average-high diversity values, and low dominance; whereas the Jaccard index indicated the existence of average similar farms as to the herbaceous-arboreal species, and floristically-differing arboreal species. The study demonstrated unsustainable management of agro diversity.
Conclusions: The farms differed floristically regarding the arboreal plants, and were average different for the herbaceous plants, whereas the Agricultural Diversity Index evidenced the implementation of unsustainable management practices to agroecosystems, which did not include the application of agroecological principles, and management aiming to increase income rather than the protection of the ecosystem. Consequently, the production and management model implemented is ecologically unsustainable.

Keywords: agrobiodiversity, agroecosystem, diversity of ecosystems, diversity of species.

Introduction

Plant formations are intermediate elements of natural factors (rain and wind) and the soil. If the soil is deprived of vegetation, the water drops fall and spatter hundreds of tons of particles of the soil, then they are easily dragged by the water sheet that runs on the surface (Alonso-Torrens et al., 2016).

Plant formations constitute natural factors at man's disposal to change water movement, besides being a barrier between the rain and the soil.

These elements have increased the recognition of the importance and the valuation of biodiversity, since human activity has compromised the goods and services of ecosystems, and consequently, affected the present and future well-being of humankind (Millennium Ecosystem Assessment 2005, cited by the National Commission for Knowledge and Use of Biodiversity, 2014, p.10).

In that sense, the farming processes are affected by the technology available and the cultural decisions of different groups that fight over the access to natural resources and the allocation of production for household consumption and sales (Díaz, Rodríguez-Sperat & Paz, 2018).

The farm sectors are among the largest users of biodiversity, but they have the potential of contributing to its protection, provided they are managed sustainably. It can lead to ecosystemic functions of relevance, like the maintenance of water quality, the cycle of nutrients, the formation and rehabilitation of the soil, erosion control, carbon storage, resilience, the creation of habitats for wild species, biological pest control, and pollinating (United Nations Organization for Food and Agriculture [FAO], 2018, p.6).

Biodiversity is critical for food safety, nutrition is necessary to produce enough foods sustainably, to cope with challenges like climate change, populational growth, and changes in people's feeding habits. Therefore, the agricultural systems are indispensable, along with the maintenance of the biological diversity to produce foods and conserve the ecological backgrounds needed to support life and the means of subsistence (FAO, 2018, p. 6).

The farming style has a great impact on agrobiodiversity, so it is necessary to identify the key components of agrobiodiversity and their effect on different farming styles, to encourage practices that promote and ensure their conservation (UNEP, 1997, cited by Stupino, Ferreira, Frangi & Sarandón, 2007, p. 339).

Agrobiodiversity is a key component of agroecosystems, as they offer ecological goods and services, such as pests and disease control, and genetic resources with medical, medicinal, and nutritional importance (Collins & Qualset, 1999; Gliessman, 2001, cited by Stupino, Ferreira, Frangi & Sarandón, 2007, p. 339).

In terms of agrobiodiversity, farms constitute agroecosystems, with a rich variety and capacity for adaptation to changing conditions, which generally makes them resilient compared to their agricultural setting (Galluzzi, Eyzaguirre & Negri, 2010).

This glance at resilience from a socioecological standpoint is an invitation to explore the cropland based on the elements that define it as an appropriate space for its caregivers, with meanings and appraisals associated with their daily and generational experiences. (Díaz et al., 2018).

Likewise, a spatial interpretation of the ecosystems as landscapes in which the agroecosystems are immersed, makes them the recipient of sociocultural and historical values in which life stories and landscape changes are inseparable (Cortés-Gutiérrez & Matiz-Guerra, 2015).

FAO (n.d.) refers that agroecosystems are "ecosystems in which humans have exerted an intentional selectiveness over the composition of living organisms. The agroecosystems comprise human populations and economic and ecological-environmental dimensions. They differ from non-managed ecosystems in that they are altered purposedly, and are often managed intensively to provide foods, fiber, and other products".

The global threats to biodiversity must not remain distant from scholars, as it covers 25-30% of the world's soils. Perhaps, it is one of the main activities affecting biodiversity, and one of the most important reasons to maintain natural biodiversity is that it provides the genetic base of all crops and animals. Hence, the genetic erosion in areas where small farmers are driven by modern agriculture to adopt new varieties at the expense of the already existing ones is a permanent concern (Altieri, 1992).

The totality of domestic crops derives from wild species that were modified through domestication, selective breeding, and hybridization. (Altamirano, Amador & Montalván, 2017).

In Cuba, the studies of integrated agroecological productive scenarios are not abundant, though many agroecosystems project into integrated farming. "The successful and outstanding experiences are more commonly embraced by small farmers [...] or exceptional cooperatives as part of urban agriculture [...]" (González et al., 2018, p. 22).

Several ANAP programs have a cooperative vision, through the farmer-farmer movement, and research is done, using parameters and indexes to reach sustainability (Ortiz, Angarica & Guevara-Hernández, 2014).

In the province of Camagüey, conservation actions, technological innovation, and the implementation of an international project Environmental Bases for Local Food Sustainability (BASAL), among other practices, help strengthen the development of capacities on household farms (Torres, 2019).

Materials and methods

The research study took place between September 2017 and May 2018. Four ANAP farms of the municipality of Camagüey were chosen for the study, on typical grayish brown soil.

Farm El Regreso de Los Viera, acquired through Decrees 259 and 300, located on 21^0 20´ 24,38´´, north latitude, and 77^0 53´ 09,3´´, west longitude. It was acquired by the current owner in 2009, who mainly produces various crops. The proprietor is Jorge Viera, who comes from a farm family.

Farm EL Malecon is located on 21^0 20´ 38,8´´ north latitude, and 77^0 53´ 14,7´´, west longitude. It produces fruits, which are processed in a small industry. The main income of the farm is the sales of processed fruit. The owner is Emilio Garcia, from a farm family, who bought the property in 1998.

Farm Villa Luisa is located on 21^0 20´ 27,8´´, north latitude and 77^0 53´ 36,53´´ west longitude. It is owned by Camilo Mendoza, from a farm family. It produces various crops mainly.

Farm EL Lago Los Hortas, located on 21^0 20´ 22,6´´, north latitude and 77^0 53´ 04,7 ´´ west longitude. Their income is mainly produced by the sales of various crops and fruit (mango, guava, and pineapple). The owner's name is Omar Horta, who acquired the farm in 2010. Before, he used to work in different activities than farming.

Sampling

The method used was designed and developed by Moreno (2001), which was adapted to the place.

Samples were taken from the fields, by recording the species present in an area comprising 0.24 hectares. The fields were subdivided into 6 transects (80 m x 5 m each), in 16 5 x 5 m plots. Overall, 64 5 x 5 m plots were made, to determine the presence of different plant species. The location of the transects was made at random, avoiding their intersection. The distance between transects was 20 m, maximum. An 80 m long rope was used to mark the transects, every 5 m. To mark the size of every 5 x 5 m plot, 2.5 m were measured on either side of the rope.

The study of biodiversity measures through the Alpha and Beta indexes, using the ones below:

Alpha diversity indexes

Margalef diversity indexes

D_{Mg}= S-1/ ln N

where:

S=Number of animals

N=Total number of individuals

Simpson dominance index

$\lambda = \Sigma p_i^2$

where:

pi= proportional abundance of the species *i*, that is the number of individuals of species *i* divided by the total number of individuals in the sample (pi= ni/N).

Then, to determine the diversity that influences equity or uniformity of the agroecosystem, which is contrary to the dominance, the operation 1- λ is performed, with the following analysis of the result:

Interpretation

When the value is between

0-0.33 Low diversity and high dominance.

0.34 – 0.66 Average diversity.

> 0.67 High diversity and low dominance.

The Shannon Wiener Index

H' = – Σpi x lnpi

Interpretation

Values between 0 and 1.35, Low diversity.

1.36 – 3.5 Average diversity.

Greater than 3.5 High diversity.

The Pielou Diversity Index

$E=H'/\ln S$

H´: It corresponds to the diversity values achieved.

S: Number of species collected.

Table 1. Analysis of the Pielou values calculated

Values	Explanation	
0 – 0.33	Heterogeneous abundant	Low diversity
0.34 – 0.66	Slightly heterogeneous abundant	Average diversity
>0.67	Homogeneous abundant	High diversity

Beta diversity indexes

Jaccard similitude coefficient

I_J= c/ a+b-c

Where:

a = the number of species present in site A

b = the number of species present in site B

c = the number of species present in sites A and B

Table 2. Analysis of the Jaccard values calculated

Range	Significance	
0 – 0.33	Unlike	Dissimilar or different floristically
0.34 – 0.66	Average similarity	Average floristic similarity
0.67 – 1	Very similar	Similar floristically

Indexes to evaluate agrobiodiversity, according to Leyva & Lores (2012)

The calculation of indexes included the integration of the different groups and components of agrobiodiversity, which represents the diversity index of the agroecosystem, which is expressed through the following mathematical function:

$$IDA = \frac{S_1IFER + S_2IFE + S_3IAVA + S_4ICOM}{St}$$

Where: IFER is the biodiversity index for human nutrition; IFE is the biodiversity index for animal nutrition; IAVA is the biodiversity index to improve the physical, chemical, and biological properties of the soils; and ICOM is the complementary biodiversity index; *St* represents the number of components in each group of agrarian biodiversity, considering that each group has a specific number of components. The indexes of each case are as follows:

$$IFER = \frac{Vi(I)+Vi(II)+Vi(III)+Vi(IV)+Vi(V) + Vi(VI)}{18}$$

$$IFE = \frac{Vi (VII) + Vi (VIII)}{6}$$

$$IAVA = \frac{Vi (IX) + Vi(X)}{6}$$

$$ICOM = \frac{Vi (XI) + Vi (XII) + Vi (XIII) + Vi(XIV)}{12}$$

Then: $$IDA = \frac{IFER + IFE + IAVA + ICOM}{4}$$

It was assumed that the *IDA* values below 0.66 were not sustainable, with being 1.0 the maximum possible value to achieve, which is hard to achieve.

Results and discussion

The characterization of agroecosystems showed differences from the findings of Vargas et al. (2016) and Vargas et al. (2017), and Céspedes, Jiménez & Estévez (2017).

During the sampling, a total of 22 314 herbaceous and shrub-like specimens were counted, pooled in 35 families, 67 genera, and 71 species. These results were below the findings of Vargas et al. (2016), and Vargas et al. (2017), and higher than the values reported by Céspedes, Jiménez & Estévez (2017) in six agroecosystems in the municipality of Minas in the dry season, but on different soils.

The arboreal plants comprised 1 161 specimens, from 23 families, 38 genera, and 49 species. Overall, the plant species totaled 23 475 specimens, from 53 families, 100 genera, and 120 species.

The diversity of plants recorded in this paper was much higher than in the reports of Céspedes, Jiménez & Estévez (2017), in the municipality of Minas, province of Camagüey, Cuba, in the same season. However, the difference lies in the consideration of the authors that the soils of the municipality of Camagüey have better conditions for the development of different plant species. These soils are more productive than the soils of the study in Minas, generally.

Table 3. General behavior of the biological soil types in the period

Plant groups	Total individuals	Families	Genera	Species
Total	23 475	53	100	120
Herbaceous and shrub-like	22 314	35	67	71
Arboreal	1161	23	38	49

Farm diversity

To analyze farm diversity, it is necessary to mention the behavior of plant species of every biological type and taxonomic group. In that sense, Table 4 shows that except from Farm Villa Luisa, where the number of families (18) and arboreal species (35) is higher than the number of herbaceous and shrub-like species combined, in all the others, the results was the opposite. The herbaceous and shrub-like families and species were more abundant than the arboreal plants, which is reasonable, as the diversity of these groups of plants on farmland is generally higher than the arboreal species because the latter was established by the farmers with a productive or economic purpose, whereas the herbaceous species emerged spontaneously and in limitless quantities since they have mechanisms for adaptation and survival to adverse conditions that are favorable for reproduction and further development in croplands. Ultimately, their reduction in number will depend on the farming techniques used, as in Villa Luisa, whose technology for weed control is more effective than in the other agroecosystems studied. The herbaceous and arboreal families with the greatest representation on the four farms were Poaceae (6-12 species); Malvaceae (5-6 species); Fabaceae (3-6 species); and Euphorbiaceae (3-4 species). This is normal for the tropical climate conditions, which offer the optimum scenario for the development of these species (Baskin & Baskin, 1989).

In arboreal plants, the highest representativeness was observed in Villa Luisa, with five species of Rutaceae; four species of Annonaceae; and three species of Moraceae, Fabaceae, and Anacardiaceae, respectively. The most commonly found arboreal species were, *Mangifera indica* L (mango) and *Psidium guajava* L (guayaba), observed on all the farms, and *Cocos nucifera* L., which grows on three of the four farms studied. Significantly, of the arboreal species recorded on the farms, 63.27% were grown to feed humans, whereas, among the herbaceous and shrub-like plants, only 14.67% corresponded to species planted for human sustenance purposes.

These results were higher, both for the arboreal and shrub-like species, compared to the findings of Céspedes, Jiménez & Estévez (2017) on farms in the municipality of Minas, who recorded a lower number of families and species for the categories studied, also lower than the reports made by Vargas et al. (2016), Vargas et al. (2017), in agroecosystems in the province of Santiago de Cuba, on other types of soils, and the same season, but a less intense dry period in the rainy season, which favored the germination of many plant species.

Table 4. Abundance of plant species by biological type and taxonomic group

Farms	Herbaceous and shrub-like		Arboreal	
	Families	Species	Families	Species
Villa Luisa	13	32	18	35
Malecón	20	49	9	10
El Lago	18	45	13	16
El Regreso	16	34	12	12

The Margalef diversity index

The analysis of these values (Table 5) concluded that the herbaceous and shrub-like species were between 3.31 in the agroecosystem of Villa Luisa, and 6.55 in Los Horta. Most indexes indicated high biodiversity, except for Villa Luisa, in the average category.

From the arboreal category analysis shown in the table, it was confirmed that excluding the Camilo Mendoza Farm, whose diversity index was high (4.66), the other farm agroecosystems showed diversity levels that can be considered low, given the fact that the index is influenced not only by the number of species but for the number of individuals on each. It was insufficient to achieve a significant representation in most of the ecosystems studied. However, these values reported for farms in the municipality of Camagüey were higher than the ones achieved by Céspedes, Jiménez & Estévez (2017), in the municipality of Minas, both in herbaceous and arboreal plants. It must be seen as a very positive aspect of these agroecosystems since food safety is mostly conditioned by the biological diversity of agroecosystems. From an agroecological perspective, the systems with the largest crop variety represent the highest resilience and resistance to threats, such as pests, diseases, or adverse climate phenomena.

Table 5. The Margalef diversity index

Farms studied	Herbaceous and shrub-like plants	Arboreal plants
Villa Luisa	3.31	4.66
El Lago	6.55	1.38
Malecón	5.81	1.77
El Regreso	4.38	2.05

The Simpson dominance and diversity index

The calculation of Simpson's dominance and diversity indexes (Table 6) for herbaceous and shrub-like species showed low dominance values, below 0.33, and high diversity values, above 0.67. The same analysis of the arboreal category resulted in agroecosystems in Camilo Mendoza and Omar Horta, with average dominance and diversity indexes, equal to or above 0.34 for dominance, and 0.67 for diversity.

According to this study, the species dominance in agroecosystems is a limitation, since the establishment of biodiverse systems promotes a variety of ecological services in agroecosystems, which if inexistent, might cause significant costs. Likewise, agricultural biodiversity is the most relevant indicator for the overall sustainability of agroecosystems. It shows (directly or indirectly) the changes taking place in favor or against sustainability; its current and future natural abundance means economic safety for nutrition, production, trade, and food safety for the present and future generations. Hence, success will rely on the proper balance among the species established by human activity on the farms to meet their nutritional needs, and those of animals. It also must meet the needs of other individuals through sales, including its use for furniture, housing projects, fuels, medicine, soil enhancement, and other equally important roles.

These results show lower dominance indexes, and therefore higher diversity indexes of herbaceous plants compared to the findings of Céspedes, Jiménez & Estévez (2017) in agroecosystems (farms) in the municipality of Minas. However, dominance was higher while diversity was lower in the arboreal plants, on the farms in the municipality of Camagüey. The dominance indexes were also lower than the reports of Vargas et al. (2016), and Vargas et al. (2017), in agroecosystems of the province of Santiago de Cuba.

Table 6. The Simpson dominance index values by farm

Farms	Herbaceous and shrub-like dominance	Arboreal dominance
1	0.30	0.36
2	0.09	0.34
3	0.08	0.30
4	0.10	0.25

Legend: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso de los Viera.

The Shannon Wiener Index

The results of the calculations for this index (Table 7) showed that in the herbaceous and shrub-like, the diversity index values were average (1.36-3.5), while the lowest values were found on Villa Luisa (1.41), and the highest on El Lago (2.94). Regarding the arboreal species, the indexes were placed in the average diversity category on three farms, above 1.36, and below 3.5. One of the agroecosystems studied showed low diversity values (0-1.35), such as El Malecon (1.33). This index becomes relevant when equity is synonymous with diversity, a requirement of productive systems to improve the services offered by the agroecosystems in favor of sustenance and human well-being, and those of animals and the soil, and so on. It has been limited by restrictive values found in the average category in one case, showing low indexes.

Most values reported are higher than the results offered by Céspedes, Jiménez & Estévez (2017) in agroecosystems (farms) in the municipality of Minas, except for the arboreal category in dark plastic soil (2.23), in Minas. It was above all the values reported for the farms in the municipality of Camagüey for this group of plants. Comparing these results reported by Vargas et al. (2016), and Vargas et al. (2017), in agroecosystems of the province of Santiago de Cuba, including the two seasons (dry and rainy), the values were below the reports for agroecosystems in the province of Camagüey for the dry season. Nevertheless, the values found in Santiago de Cuba established a more specific plant category than the Camaguey study.

Table 7. The Shannon Wiener Index by farm

Farms	Herbaceous and shrub-like plants	Arboreal plants
1	1.41	1.42
2	2.94	1.60
3	2.77	1.33
4	2.63	1.65

Legend: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso de los Viera.

The Pielou Uniformity or Equity Index

The results of this index showed (Table 8) that excluding Villa Luisa (0.40), with a average heterogeneous agroecosystem that has average diversity of herbaceous-shrub-like species, all the others were homogeneous in terms of abundance, with a high density. As to the arboreal plant category, the behavior of agroecosystems underwent a similar trend, with Villa Luisa as the only one in the average heterogeneous category, with an average diversity (0.41).

The previous results evidenced that the distribution trend of herbaceous/shrub-like plants, as well as the arboreal plants in the agroecosystems studied, were more inclined to little uniformity as to the number of individuals that make them. It is a negative factor that affects the equity indexes and the number of services that may be rendered to the farmers and the society as a whole.

These results are below the findings of Leyva & Lores (2012). The authors achieved values from some lots, that match 1, not observed in this paper. The values of this index are more equally uniform than the ones recorded in the study in Minas Céspedes, Jiménez, and Estévez, (2017), for the herbaceous/shrub-like category, and less uniform or less diverse for the arboreal plant category.

Table 8. The Pielou Uniformity or Equitability Index

Farms	Herbaceous and shrub-like E	Arboreal E
1	0.40	0.41
2	0.75	0.73
3	0.72	0.49
4	0.75	0.66

Legend: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso de los Viera.

Beta diversity indexes

The Jaccard similitude coefficient

The values calculated for this index (Table 9) show that for the herbaceous-shrub-like species, all were in the average similar category (0.34-0.66), which meant that they were average different floristically. In the arboreal plant category, all the farms confirmed their non-alike category, with values between 0 and 0.33, which means that they are unlike or different floristically.

The analysis of these results shows that the existence of unlike or different floristically farms concerning the arboreal species, generally grown for human sustenance, are a very important element of food diversity offered to the community. It makes a contribution to food safety and in favor of sustainability, besides being a significant element for the reinstatement of the ecological balance of agroecosystems, which according to Agroecology, contributes to the reduction of pest spreading because of a higher specific and genetic diversification of agroecosystems in time and space, which is vital for the farm sector in Cuba, in which the agroecosystems of the municipality of Camagüey show a positive trend in the arboreal plant category, particularly.

The findings of this study differ from the findings of Céspedes, Jiménez & Estévez (2017), in Minas, for the herbaceous/shrub-like category, because the agroecosystems show floristic differences in the municipality, whereas, in the current research, they were average different for this category. Similar results were achieved when comparing the research done by Vargas et al. (2016) and Vargas et al. (2017), in agroecosystems of the province of Santiago de Cuba.

The arboreal species (Céspedes, Jiménez & Estévez, 2017) on farms in the municipality of Minas found that they were unlike or different floristically, with only two combinations located in the average similar or average unlike floristically categories, whereas the agroecosystems of the municipality of Camagüey were in the non-alike category, indicating their dissimilarity or differences floristically, which coincided with the reports of Vargas et al. (2016) and

Vargas et al. (2017), in agroecosystems of the province of Santiago de Cuba.

Table 9. The Jaccard similarity coefficient (Number of species between farm pairs)

Communities compared	Herbaceous-shrub-like	Trees
1 and 2	0.43	0.08
1 and 3	0.38	0.20
1 and 4	0.43	0.07
2 and 3	0.43	0.14
2 and 4	0.53	0.24
3 and 4	0.42	0.13

Legend: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso de los Viera.

Species diversity according to their role in the agroecosystems

The analysis of species' roles (Table 10) to calculate the agro diversity indexes showed that the highest values were the ones used for soil feeders, made of weed species mainly, with the highest values in El Malecon, from Emilio Garcia (41), and El Regreso de Los Viera (42). However, an element that remained negative concerning farm work is the possibility of feeding the soil with green fertilizers, an essential element to improve its chemical, physical, and biological properties, and enhance the agroproductive attributes.

The species that form agroecosystems that can be used for human nutrition showed the most outstanding values in Villa Luisa, with 29 plant species capable of providing foods for humans, while the lowest values were reported in El Regreso, with seven. In other groups, there was little diversity of agroecosystems, such as the cases of hedges, medicinal plants, flowers, and ornamental species, with very low indicators in all the agroecosystems studied.

Animal feed production was poorly represented in El Regreso and El Malecon, while El Lago was the only farm with no representation in this group, as its economic profile does not include animal breeding.

Overall, the richness of farm species showed values between 47 and 71 species, with the highest value observed in Vila Luisa, belonging to Camilo Mendoza, and the lowest in EL Regreso de Los Viera.

The diversity recorded was not high compared to the findings of Vargas et al. (2016) and Vargas et al. (2017), being proportionally higher than the results reported by Leyva & Lores (2012) in research that took three years in 15 agroecosystems, in Saragoza rural community, Municipality of San Jose de las Lajas, province of Mayabeque.

Table 10. Species diversity by their role within the agroecosystem

Groups	1	2	3	4
Human nutrition (from plants)	27	12	16	7
Nutrition from soil (weeds)	27	41	40	31
Complementary (hedges and round wood)	4	3	2	7
Complementary (medicinal)	2	3	1	-
Complementary (flowers and ornamental)	3	-	-	-
Animal feed (grass and fodder)	4	-	2	1
Soil enhancer (green fertilizers)	-	-	-	-
Total species	**67**	**59**	**61**	**46**

Legend: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso de los Viera.

Species diversity by crop groups within the agroecosystem

The analysis of species by crop groups established by the farmers with different purposes (Table 11) shows that the fruit regulators represent the highest diversity of species, with the highest values in Villa Luisa (26 species), and a presence on all the other farms, but with very low indicators. Generally, fruit trees were the predominant grown species in the agroecosystems studied. The above farm comprises 68.42% of all species, whereas the lowest index was found in EL Regreso, with 40%. It posed a limitation for the agroecosystem, showing high specialization derived from the production strategy, based on the market availability and income generation for the families.

Significantly, relevant species for human nutrition, like vegetable crops included as energy foods, were represented by 1-2 species, which in EL Lago were inexistent. Likewise, plants like beans were inexistent, as the period was characterized by above normal levels of rainfall that hindered the establishment of the crop.

Upon this analysis, the absence of an integrated agroecosystem where all the interactions of plant species can be considered by their different uses within the production systems, was a practical constraint to agroecology, in terms of soil, water, crop arrangement, recycling of materials, plant nutrition, phytosanitary control, and general productivity management. It constitutes a simplification of the ecological relations within the premise.

These results were higher than the findings of Leyva & Lores (2012) in 15 agroecosystems, in Saragoza rural community, Municipality of San Jose de las Lajas, province of Mayabeque, with 38.9%.

Table 11. Number of species by crop groups

Groups	1	2	3	4
Regulators (fruit)	26	9	9	6
Regulator (green vegetables)	2	2	2	-
Forming (legumes)	-	-	-	-
Energy (crop vegetables)	1	-	1	2
Complements (body health)	2	3	2	-
Forming (animal feeds)	4	-	2	1
Complementary for the agroecosystem, pest controller, etc.	1	1	1	-
Complementary (round wood and fuel)	2	2	3	6
Energy (grain)	-	-	1	-
Total	**38**	**17**	**21**	**15**

Legend: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso de los Viera.

Values of different diversity indexes by their role within the agroecosystem

The calculation of the overall diversity of the agroecosystem (IDA) (Table 12) showed the highest values in EL Malecon, belonging to Emilio Garcia (0.52), and lower in Villa Luisa (0.39). However, these values indicated that the agroecosystems were unsustainable when compared to the standards set, which rule that a sustainable agroecosystem must have an agricultural diversity index equal to or higher than 0.66 (Leyva & Lores, 2012), evidencing that the values on all the farms were below that figure.

The diversity index for human nutrition and the complementary index were less efficient, with the lowest values. The biodiversity index for animal nutrition showed sustainability values in El Malecon (0.83) and El Regreso (0.67), whereas the biodiversity index to improve the physical, chemical, and biological properties of soils showed the same values for all the farms (0.50). It was represented by species that develop spontaneously in crop areas that can be part of the soil for replacing the elements removed by crop absorption, while the alternative implemented to enhance the agroproductive properties of the soil was almost null. It points to the need for further efforts to achieve a balance of agroecosystems by promoting a larger diversity of the species established, which play a relevant role in production and farm sustainability of production, due to the services that the soil will provide not only to the family but the community as a whole, including for animal nutrition.

These results are comparable to the findings of Leyva & Lores (2012) in 15 agroecosystems, in Saragoza rural community, Municipality of San Jose de las Lajas, province of Mayabeque. The agroecosystems values reported for the municipality of Camagüey, province of Camagüey were below the values found in the literature reports, which indexes considered unsustainable (<0.66%), whereas the study in Mayabeque showed sustainability (>0.66).

Table 12. Farm agrobiodiversity indexes

FARMS	IFER	IFE	IAVA	ICOM	IDA
1	0.39	0.33	0.50	0.33	0.39
2	0.33	0.50	0.50	0.33	0.42
3	0.33	0.83	0.50	0.42	0.52
4	0.17	0.67	0.50	0.33	0.42

Notes: 1-Villa Luisa; 2- El Lago; 3- El Malecon; 4- El Regreso. **Index of biodiversity for** human nutrition (**IFER**); animal nutrition (**IFE**); to enhance the physical, chemical, and biological properties of soils (**IAVA**); complementary biodiversity index (**ICOM**); and agricultural diversity index (**IDA**).

Conclusions

The assessment of the biological species resulted in the existence of higher diversity and abundance of herbaceous species.

The Alpha diversity indexes showed a trend to average-high diversity values, and low dominance. There are average similar farms regarding the herbaceous-arboreal species, and differing floristically in the arboreal species. The model for production and management of the farms studied is ecologically unsustainable.

Author contribution

Yudelkis González Portelles: research planning, field work, data processing, redaction of the manuscript.

Jose Luis Cespedes Cancino: research planning, fieldwork, data processing, redaction of the manuscript, final review.

Concepcion de la Torre Rodriguez: data processing, redaction of the manuscript.

Conflicts of interests

They are not declared.

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