Similarity and Convergence of Plant Composition as Tools for the Sustainable Management of Suburban Farms in Santiago de Cuba, Cuba

Similitud y Convergencia de la Composición Vegetal como Herramientas para la Gestión Sostenible de Fincas Suburbanas en Santiago de Cuba, Cuba

Semelhança e Convergência da Composição Vegetal como Ferramentas para a Gestão Sustentável de Propriedades Suburbanas em Santiago de Cuba, Cuba

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Abstract

Similarity analysis is widely used to compare plant communities, and its interpretation typically focuses on extreme values, while intermediate ranges have received less conceptual attention. The objective of this study was to determine the similarity and convergence of plant composition among suburban properties in Santiago de Cuba using ecological indicators, as a basis for developing strategies aimed at their sustainable management. Once the properties were selected, 100 m² plots were surveyed. After identifying the species, those belonging to the same category were counted; this data was used to assess species richness, as well as ecological association and subordination. A Convergence Matrix was designed as a graphical tool for ecological interpretation based on specific ranges of similarity indicators associated with a color category according to each index. Species richness varies both across farms and over time, although it is considered high (>5) in all cases. Associations (16) with similarity values between 0.41 and 0.60 predominated, as did comparisons (18) with ecological subordination between 46% and 65%; for both indicators, this is classified as moderately effective and is assigned blue according to the color scale. In general, few effective associations and subordination relationships were observed in both evaluated periods; however, it is noteworthy that no values for these indicators showing less effective behavior were observed either. The plant diversity of the evaluated suburban properties exhibited marked spatiotemporal variability; similarity analysis allowed for the identification of groups of properties with similar plant composition, and the proposed chromatic-scale convergence matrix facilitated the integrated representation and interpretation of the ecological indicators used.

Keywords: association, biodiversity, management, matrix, subordination.

Resumen

El análisis de la similitud es ampliamente utilizado para comparar comunidades vegetales y su interpretación suele centrarse en valores extremos, mientras que los rangos intermedios presentan menor desarrollo conceptual. El trabajo tuvo como objetivo determinar la similitud y convergencia de la composición vegetal entre fincas suburbanas de Santiago de Cuba mediante indicadores ecológicos, como base para el desarrollo de estrategias orientadas a su gestión sostenible. Seleccionadas las fincas fueron levantadas parcelas con una dimensión de 100 m2. Luego de identificadas las especies, se contabilizaron aquellas que pertenecieron a una misma categoría, datos que se utilizaron para la evaluación de la riqueza de especies, así como la asociación y la subordinación ecológica. Se diseñó una Matriz de Convergencia como herramienta gráfica para la interpretación ecológica basada en rangos específicos de indicadores de similitud asociados a una categoría cromática según cada índice. La riqueza de especies mantiene un comportamiento variable tanto entre fincas como por períodos, aunque para todos los casos se considera elevada (>5). Predominaron las asociaciones (16) con valores

de similitud entre 0,41 y 0,60; así como comparaciones (18) con subordinación ecológica entre el 46 y el 65 %, lo que para ambos indicadores se clasifica como medianamente efectiva y se le asigna el color azul según la escala de colores. De manera general en ambos períodos evaluados se observan pocas asociaciones y subordinaciones efectivas, aunque resulta interesante que tampoco se observaron valores para estos indicadores que muestre un comportamiento menos efectivo. La diversidad vegetal de las fincas suburbanas evaluadas presentó una marcada variabilidad espaciotemporal, el análisis de similitud permitió identificar grupos de fincas con composición vegetal semejante y la matriz de convergencia con escala cromática propuesta facilitó la representación e interpretación integrada de los indicadores ecológicos utilizados.
Palabras clave: asociación, biodiversidad, manejo, matriz, subordinación.

Resumo

A análise de similaridade é amplamente utilizada para comparar comunidades vegetais e a sua interpretação costuma centrar-se em valores extremos, enquanto os intervalos intermédios apresentam um menor desenvolvimento conceptual. O trabalho teve como objetivo determinar a semelhança e a convergência da composição vegetal entre propriedades suburbanas de Santiago de Cuba, através de indicadores ecológicos, como base para o desenvolvimento de estratégias orientadas para a sua gestão sustentável. Após a seleção das propriedades, foram demarcadas parcelas com uma área de 100 m². Após a identificação das espécies, foram contabilizadas aquelas que pertenciam a uma mesma categoria, dados que foram utilizados para a avaliação da riqueza de espécies, bem como da associação e da subordinação ecológica. Foi concebida uma Matriz de Convergência como ferramenta gráfica para a interpretação ecológica, baseada em intervalos específicos de indicadores de similaridade associados a uma categoria cromática, de acordo com cada índice. A riqueza de espécies apresenta um comportamento variável tanto entre explorações como ao longo dos períodos, embora, em todos os casos, seja considerada elevada (>5). Predominaram as associações (16) com valores de similaridade entre 0,41 e 0,60, bem como as comparações (18) com subordinação ecológica entre 46 % e 65 %, o que, para ambos os indicadores, é classificado como medianamente eficaz e a que é atribuída a cor azul de acordo com a escala de cores. De um modo geral, em ambos os períodos avaliados, observam-se poucas associações e subordinações efetivas, embora seja interessante notar que também não se observaram valores para estes indicadores que revelassem um comportamento menos efetivo. A diversidade vegetal das propriedades suburbanas avaliadas apresentou uma marcante variabilidade espaço-temporal; a análise de similaridade permitiu identificar grupos de propriedades com composição vegetal semelhante e a matriz de convergência com a escala cromática proposta facilitou a representação e a interpretação integrada dos indicadores ecológicos utilizados.
Palavras-chave: associação, biodiversidade, gestão, matriz, subordinação

Introduction

Contemporary agriculture faces the challenge of increasing food production while maintaining the provision of essential ecosystem services. The development of simplified production models, with a high dependence on external inputs, has contributed to loss of biodiversity, the degradation of natural resources, and a reduction in the resilience of agricultural systems (Knapp & Sciarretta, 2023). In this context, the transition toward sustainable agri-food systems requires approaches based on ecological principles that integrate production, resource conservation, and environmental stability.

Plant diversity is one of the fundamental components for the sustainability of agroecosystems, as it influences key ecological processes (nutrient cycling, regulation of biological populations, soil conservation, and productive stability). According to Teixeira et al. (2021), agricultural systems with greater plant diversity can enhance soil quality and the provision of ecosystem services, particularly when system management promotes positive interactions among the components. Thus, species diversity is not only a structural characteristic of plant communities but also an indicator of ecological functioning and adaptive capacity.

Small-scale agricultural systems, particularly urban and suburban ones, play a strategic role in local areas by simultaneously contributing to food production, the conservation of biological resources, and the provision of ecosystem services. These areas exhibit high plant heterogeneity resulting from the coexistence of cultivated wild species, as well as trees, which form complex plant communities that promote biodiversity within highly transformed landscapes (Seitz et al., 2022). Viewed in this light, suburban farms are multifunctional production units where vegetation composition is a key element for generating ecosystem services and assessing the degree of sustainability (Nicholls et al., 2020; Zhou et al., 2022).

In Cuba, suburban and family farming is a strategic component, as it enables local food supply and efficient land use, while incorporating agroecological practices that reduce the use of external inputs. Rodríguez et al. (2023) noted that this production system has gained prominence in agricultural policies because it integrates production, resource conservation, and local producer participation. Likewise, Suris & González (2015) emphasized that increased biodiversity on family and suburban farms enhances the resilience of Cuban production systems in the face of adverse events (climatic and/or phytosanitary).

Studies conducted on suburban farms in Santiago de Cuba have shown that these farms are systems of high floristic complexity, where herbaceous, shrubby, and tree species coexist (Vargas et al., 2016; Vargas et al., 2019; Candó et al., 2020; Vargas et al., 2020; Rodríguez et al., 2025) and cultivated species (Vargas et al., 2017; Ramos et al., 2021; González et al., 2021; Vargas et al., 2021 a, b, and c). These plants form plant communities that result from local environmental conditions and the management practices employed by producers.

All the authors cited above identified significant plant diversity on suburban farms in Santiago de Cuba, with differences in species richness, dominance, and floristic composition among production units. This demonstrates that plant structure is a distinguishing factor in characterizing the ecological functioning of these systems. More recently, Vargas et al. (2022) and Vargas et al. (2023) confirmed that the composition and diversity of the flora on these farms vary depending on the climatic period and the specific characteristics of each property, which indicates the existence of distinct patterns of plant organization.

La utilización de índices ecológicos constituye una herramienta ampliamente aceptada en estudios de biodiversidad, debido a que permiten evaluar riqueza, composición y grado de similitud entre comunidades vegetales bajo diferentes condiciones ambientales o de manejo. Moreno (2001) planteó que los índices de diversidad y similitud ayudan a interpretar la estructura de comunidades biológicas y establecer comparaciones entre unidades ecológicas. En agroecosistemas, permiten la identificación de características semejantes que puedan ser consideradas modelos de manejo sostenible. El análisis comparativo de la fitodiversidad entre fincas representa una alternativa metodológica en la toma de decisiones orientado al diseño de estrategias de gestión adaptadas a las condiciones locales.

Although progress has been made in biodiversity studies of Cuban agricultural systems, there is still a need to further explore the use of plant similarity as a tool to guide sustainable management at the farm level. Grouping farms according to their floristic composition can facilitate the transfer of successful experiences and the establishment of differentiated management strategies, since each farm is a socio-ecological system that is environmentally, productively, and culturally distinct. Under this approach, assessing the similarity in plant diversity on suburban farms in Santiago de Cuba is a way to obtain basic information for achieving more resilient production systems.

Although similarity indices are widely used tools for comparing plant communities, their interpretation tends to focus on extreme values, while intermediate ranges have received less conceptual attention. Graphical representation using convergence matrices with color scales defined according to the ecological significance of the indicators used can facilitate the interpretation of similarity among production units and provide an integrated view of plant composition patterns. The objective of this study was to determine the similarity and convergence of plant composition among suburban properties in Santiago de Cuba using ecological indicators, as a basis for developing strategies aimed at their sustainable management.

Materials and Methods

The research was conducted on seven

suburban farms in the municipality of Santiago de Cuba, located in the province of the same name, during the period from December 2019 to September 2022. This timeframe encompasses the two seasons considered in the development of agriculture in Cuba: the rainy season and the dry season. The procedure used in each phase of the study is described below.

Selection of Farms

The suburban agroecosystems selected by del Toro et al. (2018) and del Toro et al. (2019) were visited. The names, geographic coordinates, and elevation in meters above sea level (masl) of the study sites are as follows (Table 1).

Table 1. Farms selected for the study and their geographic locations.

Fincas	Latitud norte[1]	Longitud oeste[1]	Altura (msnm)
Erick Vega	20.091236	-75.786977	150
La Esperanza	20.047084	-75.791690	48
Tres Palmas	20.064135	-75.801778	75
La República	20.068167	-75.801893	75
La Caballería	20.047843	-75.794819	43
Los Cascabeles	20.057827	-75.800777	54
La Juliana	20.086979	-75.793355	105

*Tipo de suelo: Pardo Sialítico Mullido sin Carbonato (todos los casos)

1Based on decimal coordinates

Conducting field surveys

Once the plots were selected, the species count was conducted. For this count, plots measuring 100 m² (10 m × 10 m) were established as sampling units, in accordance with the methods used by Zacarías et al. (2012) and Ramírez et al. (2013). The plots were marked off with wooden stakes at their four corners and surveyed in a clockwise direction. It is worth noting that the number of sampling units varied (between 40 and 700) depending on the area of each farm, and that the same plots were used in both evaluation periods, always ensuring that at least 70% of the farm's total area was sampled.

The information obtained from the species count (common names of the species and total number of individuals) in each of the surveyed plots was recorded on field sheets. Using the data, the plant species were identified at the Department of Agronomy at the University of Oriente. In this process, the Botanical Dictionary of Cuban Common Names by Roig (1988) was used; the scientific names obtained were cross-referenced with the work of Acevedo & Strong (2012) and updated using the work of Greuter & Rankin (2017). Those species that proved difficult to identify using the method described above were taken to the Herbarium of the Eastern Center for Ecosystems and Biodiversity (BIOECO) to be identified by specialists.

Assessment of species richness

Once the different species were identified, the number of species belonging to the same taxonomic category was counted; these data were used to calculate certain indices described by Moreno (2001) and Pérez (2004), which were employed for biodiversity analysis. In this regard, species richness values were calculated using the Margalef index (DMg), as shown in Eq. (1).

$$DMg = \frac{S-1}{\ln N} \qquad \textit{(Eq. 1)}$$

Where:

S: number of species
N: total number of individuals

The species richness obtained were classified according to the ranges used by Lara (2009), where values < 2 represent low species richness, values between 2 and 5 indicate moderate species richness, and values > 5 represent high species richness.

Construction of the Convergence Matrix and Chromatic Interpretation

First, similarity values were calculated using Sørensen's association index (S) (Eq. 2) and the Ecological Subordination index (SE) (Eq. 3).

$$S = \frac{2c}{a + b} \qquad \textit{Eq. 2}$$

Where:

a = number of species in sample A
b = number of species in sample B
c = number of species common to both samples

$$SE = \frac{C}{N} \qquad \textit{Eq. 3}$$

Where:

C = number of species common to both A and B
N = number of species in the community with the lower species richness among the two being compared

It is worth noting that, for the association index, the specialized literature does not report a specific value; it only states that it must fall between 0 and 1, and that as it approaches one of these extremes, it will be considered whether it is increasing or decreasing. In the case of Ecological Subordination, no specific value is reported; it is merely stated that for it to be effective, it must be equal to or greater than 66%. From the above, both indicators have different ecological classifications and meanings, but they are limited to extreme values, which makes their representation and interpretation difficult.

Therefore, a Convergence Matrix was designed as a graphical tool for ecological interpretation based on specific ranges of similarity indicators (Sørensen's index and Ecological Subordination), for which interpretive ranges were established according to each index. Each range was assigned with a color category to facilitate the visualization of convergence levels among farms (Figures 1 and 2).

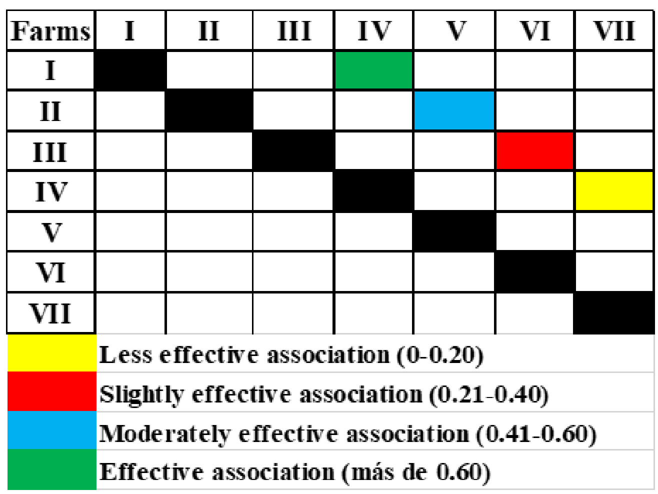

Figure 1. Color-coded convergence matrix for Sørensen's association index.

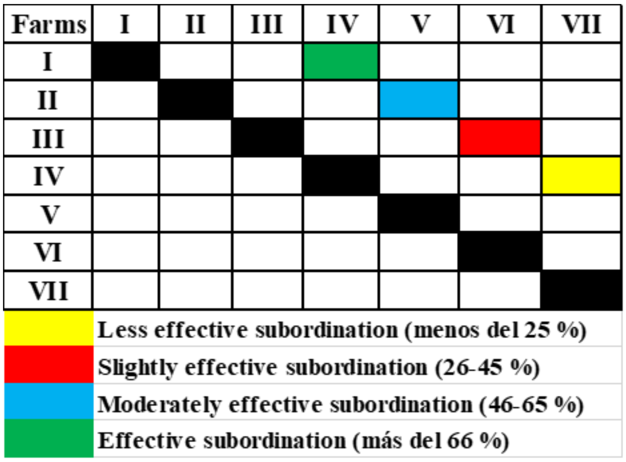

Figure 2. Color-coded convergence matrix for the Ecological Subordination Index.

Interpretive ranges for the Sørensen association index:

- Least effective association: few or no shared species, indicative of dissimilarity; species composition is very or completely different between the communities being compared

- Slightly effective association: low similarity; presence of shared species between the communities being compared, but very limited

- Moderately effective association: moderate or average similarity (slightly below or above the mean value); the number of common species is roughly similar to the number of non-common species

- Effective association: high or complete similarity; the number of shared species is greater than the number of non-shared species

Interpretive ranges for the Ecological Subordination Index:

- Less effective subordination: few or no shared species; no subordination of the community with lower species richness to the one with higher species richness; species highly adapted to the specific conditions of each site

- Slightly effective subordination: low subordination; few common species between the communities being compared; the community with lower species richness is represented in the one with higher species richness, but only very limited; some species adapted to the conditions of both units being compared are present

- Moderately effective subordination: moderate or average subordination; the community with lower species richness is represented in the one with higher species richness; the number of species adapted to the conditions of the two units being compared is slightly lower or higher than the average value

- Effective subordination: high or total subordination; the community with lower species richness is highly or fully represented in the one with higher species richness; the species in the two units being compared are adapted to the conditions of both sites

Results and Discussion

As can be seen (Figure 3), species' richness varies both across farms and over time. Higher species richness was found within the farms during the rainy season, except at La Juliana Farm, where there was a slight decrease compared to the dry season. This pattern may be related to the growth of non-crop species, which are a component of plant diversity in agricultural ecosystems - that may find favorable conditions for their development with the arrival of rain. Added to this is the fact that farmers may have introduced cultivated plant species that were not present in the previous period, which coexist with species that were already present on the farm.

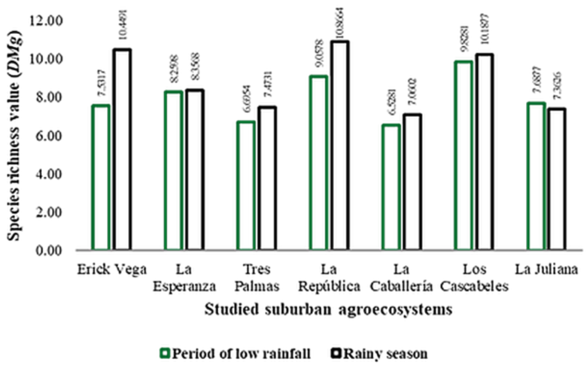

Figure 3. Trends in species richness on the study farms by evaluation period.

On the other hand, it is known that species richness is not an indicator of similarity when comparing different areas. However, the value it attains in the units being compared may be indicative of similarity in behavior within the unit, considering the specific characteristics that determine such behavior (environmental conditions, management practices, dominant species). Based on the classification ranges described, it can be said that all the farms under study have high species richness. However, it should be noted that, based on the values obtained for this index, three groups can be identified during the dry season and two during the rainy season, according to the similarity of the richness values achieved (Table 2).

Table 2. Groups of farms by period based on the similarity of the calculated wealth value.

Dry Season		Rainy Season	
Groups	**Farms**	**Groups**	**Farms**
I	Tres Palmas, La Caballería	I	La Esperanza, Tres Palmas, La Caballería, La Juliana
II	Erick Vega, La Esperanza, La Juliana	II	Erick Vega, La República, Los Cascabeles
III	La República, Los Cascabeles	—	—

Based on the information in the table, it can be concluded that during the rainy season, farms maintain a level of species richness whose value shows a higher degree of similarity in numerical terms. Considering this similarity in behavior is important because it may represent an opportunity to analyze and utilize the management practices of farms with greater species richness as a basis for designing actions aimed at the sustainable management of less-favored agricultural ecosystems.

The variability observed in species richness among the farms studied demonstrates that these production systems have a heterogeneous plant structure, influenced by the interaction between environmental factors and management decisions made by farmers. In agroecosystems managed by smallholder farmers, plant diversity is determined not only by climatic conditions but also by the selection of cultivated species, conservation practices, management intensity, and the production objectives of each farm (Altieri et al., 2015; Wezel et al., 2020).

For its part, the increase in species richness during the rainy season may be associated with greater water availability, which promotes the germination, establishment, and development of spontaneous species in tropical agroecosystems. According to Teixeira et al. (2021), seasonal changes in resource availability alter the plant structure of agricultural systems, especially when biological simplification occurs. Similarly, studies on diversified agroecosystems have shown that periods with favorable environmental conditions can temporarily increase the presence of accompanying species without altering the primary productive structure (Tamburini et al., 2020).

These results are consistent with those obtained by Vargas et al. (2016) and Vargas et al. (2022) on suburban farms in Santiago de Cuba, who found differences in plant composition and species richness among production units, associated with both the specific characteristics of each farm and the management practices applied by the farmers. This confirms that suburban farms should be considered socio-ecological systems where plant diversity reflects the interaction between the environment, productive culture, and human decisions.

However, although richness is a useful indicator for describing plant diversity, it should not be interpreted as a direct measure of similarity between communities. Moreno (2001) and Magurran (2004) noted that two communities may have similar richness values yet differ widely in their species composition. Therefore, identifying groups of farms with similar richness values represents only a first approximation, which must be supplemented with indices based on shared species composition.

Species richness is an indicator that can have a significant influence on similarity indices. This is because the greater the richness of the species of an area, the higher the probability of finding common species when comparing it to another area. The results obtained for the Sørensen Index (Similarity) are shown below.

As can be seen (Figure 4), during the dry period, in 16 of the 21 communities being compared, the Sørensen index takes on values greater than 0.41 and less than 0.60; therefore, these communities are considered moderately effective and are assigned blue according to the color scale. This is associated with moderate or average similarity (slightly below or above the mean value), which results from the number of species shared between the compared units being roughly similar to the number of species not shared.

Farms	EV	LE	TP	LR	LC	LCs	LJ
EV		0.51	0.46	0.48	0.39	0.46	0.63
LE			0.43	0.49	0.32	0.54	0.45
TP				0.51	0.51	0.48	0.42
LR					0.38	0.48	0.46
LC						0.39	0.41
LCs							0.55
LJ							

Figure 4. Level of association among farms during the dry season.

Legend: EV: Erick Vega, LE: La Esperanza, TP: Tres Palmas, LR: La República, LC: La Caballería, LCs: Los Cascabeles, LJ: La Juliana

Only the Erick Vega, La Caballería, La Esperanza, La Caballería, La República, La

Caballería, and La Caballería, Los Cascabeles associations are considered ineffective (red), with values exceeding 0.20 but falling below 0.40. This is due to low similarity, given the limited presence of common species among the communities being compared. The Erick Vega-La Juliana association was the only one that proved effective (Green), with values exceeding 0.61, indicating high similarity, where the number of common species is greater than that of uncommon species.

For the rainy season (Figure 5), there is a decrease in moderately effective associations and an increase in less effective ones. Of the 21 pairings compared, only 14 were moderately effective, and two were added to the "slightly effective" category; the pairings in this category include Erick Vega-La Caballería, La Esperanza-La Caballería, La Esperanza-La Juliana, Tres Palmas-La Caballería, La República-La Caballería, and La República-La Juliana. A notable finding is that the Erick Vega-La República partnership moved from being moderately effective to effective from one period to the next.

Farms	EV	LE	TP	LR	LC	LCs	LJ
EV		0.56	0.53	0.64	0.38	0.47	0.46
LE			0.4	0.49	0.34	0.41	0.38
TP				0.46	0.39	0.42	0.4
LR					0.33	0.43	0.37
LC						0.42	0.46
LCs							0.46
LJ							

Figure 5. Level of association among farms during the rainy season.
Legend: EV: Erick Vega, LE: La Esperanza, TP: Tres Palmas, LR: La República, LC: La Caballería, LCs: Los Cascabeles, LJ: La Juliana

The predominance of intermediate similarity values among farms indicates that, although they share a significant proportion of species, each production unit maintains a distinct plant composition. According to Kremen & Merenlender (2018), this pattern is characteristic of family and suburban agroecosystems, where farmers' decisions have a decisive influence on the presence and persistence of plant species.

The decrease in similarity during the rainy season is one of the most interesting findings of the study. Although one might expect more favorable environmental conditions to promote floristic convergence among farms, the increase in wild species and the differential response of each farm may increase plant heterogeneity. In this regard, Dainese et al. (2019) and Tamburini et al. (2020) argued that the biological diversification of agroecosystems depends on both environmental factors and local management practices, resulting in plant communities with unique configurations.

This result is consistent with Vargas et al. (2022), who found that suburban farms in Santiago de Cuba exhibit floristic differences related to the specific conditions of each production system. The temporal variation observed in similarity demonstrates that these farms do not function as static plant communities, but rather as dynamic systems where agricultural practices continuously modify species composition.

From a management perspective, the existence of groups of farms with greater similarity allows for the identification of production units that could share management strategies. However, the absence of complete homogeneity suggests that actions aimed at achieving sustainability must be adapted to the specific characteristics of each farm and should not be based exclusively on general models.

A pattern like the one described above is observed in the case of ecological subordination. As can be seen during the low-rainfall period (Figure 6), of the 21 comparisons analyzed, 18 showed moderately effective subordination ranging from 46% to 65%. These are considered average or moderate values of subordination, where the community with lower species richness is represented in the one with higher species richness, and the number of species adapted to the conditions of the two units being compared is slightly below or above the average value.

Farms	EV	LE	TP	LR	LC	LCs	LJ
EV		56%	47%	56%	40%	56%	58%
LE			45%	51%	37%	59%	47%
TP				59%	53%	58%	64%
LR					47%	50%	46%
LC						53%	50%
LCs							58%
LJ							

Figure 6. Level of subordination among farms during the dry season.
Legend: EV: Erick Vega, LE: La Esperanza, TP: Tres Palmas, LR: La República, LC: La Caballería, LCs: Los Cascabeles, LJ: La Juliana.

The comparisons Erick Vega-La Caballería, La Esperanza-Tres Palmas, and La Esperanza-La Caballería show low subordination. This reflects low subordination and a scarce presence of common species among the communities being compared; the community with lower species richness is represented in the one with higher species richness, but only very limitedly, indicating that some species adapted to the conditions of the two units being compared are present. No effective subordination was observed among any of the farms being compared.

This pattern varied substantially during the rainy season (Figure 7). This is because, of the 21 comparisons made, nine (La Esperanza-Tres Palmas, La Esperanza-La Caballería, La Esperanza-La República, La Esperanza-La Juliana, Tres Palmas-La Caballería, Tres Palmas-La Juliana, La República-La Caballería, La República-Los Cascabeles, La República-La Juliana) fell into the "slightly effective" range, representing an increase of +6 compared to the previous period. However, the Erick Vega-La República comparison showed effective subordination exceeding 66%.

Farms	EV	LE	TP	LR	LC	LCs	LJ
EV		59%	63%	67%	46%	47%	51%
LE			45%	54%	40%	43%	40%
TP				58%	40%	51%	43%
LR					43%	45%	42%
LC						51%	51%
LCs							46%
LJ							

Figure 7. Level of subordination among farms during the rainy season.
Legend: EV: Erick Vega, LE: La Esperanza, TP: Tres Palmas, LR: La República, LC: La Caballería, LCs: Los Cascabeles, LJ: La Juliana.

This finding reveals a high level of subordination, where the community with lower species richness has a high presence in the community with higher species richness because the species from both farms are adapted to the conditions of both sites.

The values obtained for ecological subordination indicate that the farms share common species, but there is no strong structural dependence among them. This pattern is to be expected in agricultural systems managed by individual farmers. This demonstrates that plant composition is influenced by specific decisions related to production, resource availability, and cultural preferences.

According to Estrada et al. (2022) and Priyadarshana et al. (2024), spatial heterogeneity is a fundamental characteristic of biodiverse agroecosystems, as different production units can develop distinct plant configurations without losing ecological functionality. In this regard, the low prevalence of effective subordination should not be interpreted as a limitation, but rather as evidence of structural diversity among production systems. Meanwhile, the increase in low-effectiveness subordination during the rainy season can be explained by the temporary introduction of new species and by the differential growth of spontaneous species. These processes generate changes in the relative composition of plant communities and reduce the proportion of species shared among farms.

From a sustainable management perspective, these results indicate that farms with greater species richness and higher similarity values can serve as benchmarks for designing management strategies, which should be tailored to the specific conditions of each farm. As noted by Wezel et al. (2020), agroecology does not seek to standardize production systems but rather to strengthen ecological processes adapted to local contexts.

The convergence matrix made it possible to visualize differences in the degrees of similarity among farms, as well as to identify groups with greater floristic affinity and units with more distinct plant composition. All of this would be less evident through direct inspection of the numerical coefficients. Values represented in the upper color categories indicate greater similarity in plant composition, while the lower categories reflected less floristic correspondence. This approach facilitates the ecological interpretation of the results and can serve as a useful tool for comparative studies of plant diversity.

The convergence matrix presented here serves as a complementary tool for interpreting ecological indicators, particularly for intermediate values where conventional criteria offer less discriminatory power. The incorporation of color ranges based on the ecological interpretation of each index made it possible to transform numerical values of similarity and subordination into visual categories that are comparable across production units.

In general, few effective associations and subordinations were observed in both periods evaluated; however, it is interesting to note that no values for these indicators showing less effective behavior were observed either. It should not be forgotten that the ecosystems analyzed belong to the group of anthropogenic ecosystems, which implies that humans manage them according to their own interests.

Overall, the results show that suburban farms in Santiago de Cuba exhibit high plant dynamics determined by the interaction between climatic factors and management decisions. The diversity observed does not follow a uniform pattern but rather reflects the specific characteristics of each production system. This heterogeneity is a defining feature of diversified agroecosystems and can be leveraged to establish differentiated sustainable management strategies, with farms exhibiting the best attributes of plant richness, similarity, and organization serving as benchmarks.

Conclusions

The plant diversity of the suburban farms evaluated showed marked spatiotemporal variability, given the differences in species richness and patterns of floristic similarity across the two periods studied; this confirms that their species composition is determined by the interaction between environmental conditions and the management practices employed by farmers.

The similarity analysis made it possible to identify groups of farms with similar plant composition, while also serving as a useful tool to support the sustainable management of suburban agroecosystems, since properties with better diversity attributes can be considered benchmarks to guide management actions adapted to the ecological and productive characteristics of each farm.

The proposed chromatic-scale convergence matrix facilitated the integrated representation and interpretation of the ecological indicators used, while also allowing for the identification of patterns of similarity in floristic composition among suburban farms.

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