International Journal of Life Science and Agriculture Research
ISSN (Print): 2833-2091, ISSN (Online): 2833-2105
Volume 04 Issue 05 May 2025
DOI: https://doi.org/10.55677/ijlsar/V04I05Y2025-02
Impact Factor: 7.88 , Page No : 292-299

Evaluation of the Agrobiodiversity Index (IDA) in the Yumurí Valley, Matanzas, Cuba

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ABSTRACT

Agrobiodiversity is the guarantee that localities have to achieve food sovereignty. Knowing its presence by locality in correspondence with its utilitarian values, allows determining the degree of approach to food sovereignty, nutritional education and ecological balance. However, to achieve this, it is first necessary to know in the agroecosystems the availability of food species established in the agroecosystems and the associated free species of known or unknown utility. This participatory research was carried out that consisted of the registration and evaluation of the functional diversity managed and associated with the agroecosystems of the Yumurí Valley in Matanzas, Cuba, for five years. The Agrobiodiversity Index (IDA) was applied, which makes it possible to know the functional diversity by food, human and animal group, the diversity for the protection of natural resources and the diversity associated by natural appearance with other known utilitarian values. The results showed the species deficits according to the protection needs of each group and their causes, which is why the acceptance levels were not reached (IDA ≥ 0.7) by all sub-indices (IFER 0,68; IFE 0,60; IAVA 0,50; ICOM 0,66). The study allowed us to recommend the inclusion of essential species that were absent and forgotten and to rescue those that lost their commercial importance, but were desired by the consumers. Species that raise the acceptance levels (IDA ≥ 0.7) are recommended and therefore meet local needs, and a path to follow is presented to achieve local food sovereignty and prospective sustainability, assuming agrobiodiversity as a basis.

KEYWORDS: Agrobiodiversity Index, diversity for human and animal nutrition, protection of natural resources, nutritional education, food sovereignty.

Published Online: May 05, 2025

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INTRODUCTION

Research related to agrobiodiversity has been conducted from different perspectives and ranges from the most comprehensive in terms of information emanating from data compilation on a global scale (Jones, et al, 2021; Remans, 2021) to those that assume it in a more specific way for productive systems within local agroecosystems (Altieri & Nicholls, 2013).

Leyva and Lores (2018) proposed an Agrobiodiversity Index (IDA) that indicates the degree of approach to a desired diversity value at a local scale, to comply with food sovereignty, based on adequate nutritional education and, at the same time, achieve protection of natural resources for greater ecological balance. This index has been endorsed by other authors (González et al., 2018; Martínez, 2019) and has been strengthened by the proposal of Coelho-de-Souza et al. (2018), by coining the term "Sociobiodiversity", added to which is inserted the vision of Zúñiga and Sarandón (2020) regarding food sovereignty and nutritional education.

Our research presents a study aimed at quantifying the existing physical biodiversity in the agroecosystems of the Mena community of the Yumurí Valley, Matanzas, Cuba. The aim was to know through the application of the Agrobiodiversity Index (IDA) the degree of approach to the desired diversity according to the rigors of the Index. Ass well, make in accordance with the results the pertinent corrections that guarantee a prospective local development on agroecological bases from the agrobiodiversity indicator, considered by Leyva Galán and Pohlan (2005), which are the fundamental basis of agroecology.

MATERIALS AND METHODS

This study was conducted in the Mena community, which belongs to the Yumurí River basin, one of the main ones in the province of Matanzas (Figure 1).

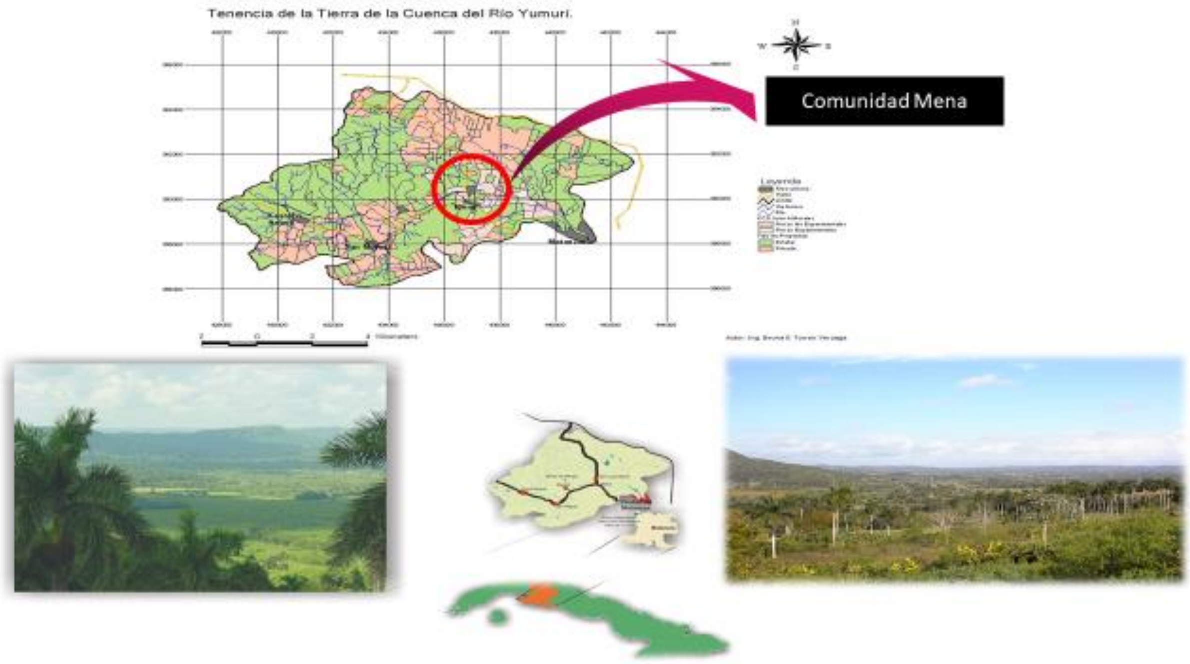

Figure 1. Study area of the Mena community in Cuba.

It includes the sub-district of plains and heights north of Havana-Matanzas and constitutes one of the most attractive physical-geographical regions in the country, due to its high diversity, natural landscape beauty, together with its floristic, cultural and historical values (Rodríguez Suárez et al., 2013). The data collection is based on the non-parametric statistical analysis of Typical Case (Stewart, 2005; ATLAS.ti Scientific, 2023) for which the people with the greatest knowledge of the locality were chosen. A group of 64 people from different specialties and experience in agriculture was formed and in an exchange workshop, ten mixed production agroecosystems (agricultural and livestock) were selected, representative of the total, and willing to participate in the research.

The research area covered an area of 273 ha, 17% of the total, amounting to 1,606 ha, the base area for the livelihood of the Mena community. With a local population of 659 people (ONEI, 2020), of which 63 were part of those selected (53% female). Their ages ranged between 35 and 65 years. The lack of agroecosystems led by women prevented balanced selection for this concept. The average annual rainfall in the Valley amounts to 1,350 mm and the Valley is located at 200 meters above sea level. The soils belong to the carbonated agro genic brown type (Hernández-Jiménez, A. et al., 2019), which are suitable for agricultural production, and it also has a river that borders the valley, which has allowed access to water to all inhabitants through their wells, although the production is obtained in dry conditions due to the lack of efficient irrigation systems. The Valley has a rainy period (May to October) where 80% of the precipitation occurs, with June and July being the rainiest months.

Functional diversity registry

Crops were recorded by annual production system between the year’s 2016 to2020 and the main crop of the locality was defined. The desired non-existent diversity and the causes of its absence were also recorded. The diversity associated with the functional diversity was assumed from previous research (Leyva Galán & Lores Pérez, 2012; Rodríguez Suárez et al., 2013) and the new appearances in the temporary fallows due to the absence of crops given the lack of resources.

Calculation of the Agrobiodiversity Index (IDA)

The Agrobiodiversity Index is based on four groups of species according to their utilitarian values and is_sustains on a relationship between the value of the existing diversity and the desired one. The species were grouped according to needs in four groups (Table 1). They are: (i) human food (FER), (ii) animal food (FE), (III) protection of natural resources (AVA) and (iv) the group (COM) representing free-growing, spontaneous species, of known or unknown human use, either or because they play other roles.

Table 1. Components of the sub-indexes (IFER, IFE, IAVA, ICOM) for calculating the IDA.

	Species groups	Breakdown by function	Utility values
IDA	Human food (FER)	Formative (two groups)	Proteins of plant and animal origin.
		Proteins of plant and animal origin Energy (four groups)	Carbohydrates; roots, tubers, cereals and oilseeds.
		Regulatory (three groups)	Fruits, vegetables and condiments.
	Animal food (FE)	Formative (two groups) Energy (two groups)	Arboreal and creeping legumes Pastures and forages.
	Protection of natural resources (AVA)	Soil, water, air, light and temperature	Green manures, conserves unburned biomass. Carbon Capture, protection of free birds and natural events.
	Associated Diversity (COM)	Flowers, ornamental weeds, medicinal plants, religious, useful for religious use, reservoir and protection of associated entomofauna among others	Alternative source of income for the farmer and his family, as well as protectors of ecological balance, honey, wood, crafts and preserved ecological niches.

After the agrobiodiversity record, there data's were submitted to the consideration of various people not included in the research to detect the existence of some species not included in the sample.

Finally, the corresponding sub-indexes were determined, establishing a list of indicators: the actual number of species existing and the total number of species desired in the community, including species not linked to food, such as green medicine, according to the participatory opinion of experts, farmers and people knowledgeable on the subject. The Agrobiodiversity Index IDA responds to the following formula:

$$IDA = \frac{S_1 IFER + S_2 IFE + S_3 IAVA + S_4 ICOM}{S_t}$$

Then the IDA = (S1 + S2 + S3 + S4 / St) where St represents the number of times that S is repeated, that is, four times.

When determining the IDA, the four sub-indexes assume the same importance value, so that any group that is not attended to affects the IDA value in the same proportion. To calculate the IDA, a relationship was established between the actual value and the desired value. As a reference for the desired ideal value, the local agroecosystem with the greatest historical diversity was assumed, plus the essential species that do not exist, but are desired by the local population and feasible according to soil and climate conditions (Gravina Hernández & Leyva Galán, 2012). The authors of the index (Leyva Galán & Lores Pérez, 2012) assumed as an input to sustainability, an agrobiodiversity value IDA $\geq$ 0.7 after establishing the relationship between the number of actual existing species and the desired value, therefore, the IDA value ranges between 0.1 and 1.0.

To calculate the IDA between 2016 and 2020, all species that were cultivated or that still remained in each agroecosystem were recorded, placed in groups by production systems. The final information resulted from the average of the five years of records.

The total species of the locality may or may not be part of the agroecosystems, given that there are species established in the ecological niches that are established around the houses, which are never part of the productive systems, but which are indicators of their productive feasibility according to their productive contributions and demand. In addition, the impossibility of producing some essential food for edaphoclimatic reasons, or another major cause, are not considered limitations of the IDA.

The increase or decline of a species is assumed when in the annual evaluation of a species it has been included or excluded with respect to the previous evaluation.

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The AVA and COM group indices (IAVA and ICOM sub-indices) are the most complex to quantify their efficiency, therefore, local actors contribute in a precise way, which are the present species that have played or play a determining role in the locality and in the case of those absent, the reasons why they no longer exist.

For these two sub-indexes, each quantitative value is assumed from a qualitative value obtained in a participatory manner and is flexible according to its importance, with an explanation of the existing real situation, as an argument for issuing the numerical value, under the same premises as the IFER and IFE sub-indexes.

RESULTS AND DISCUSSION

Results of the functional diversity

The functional diversity corresponding to human nutrition grouped into formative, energetic and regulating (IFER) species registered 62, with which a significant part of the food needs of the locality is supplied. Although it does not satisfy all the bodily needs of humans, due to the lack of essential species and therefore, it is the first indicator that limits reaching the desired figure (IDA $\geq$ 0.7). The most notable deficit was centered on the total absence of oleaginous species, something essential to guarantee Food Sovereignty (Table 2).

Table 2. Behavior of species for the sub-index IFER (human food) in the Mena community, Yumurí Valley.

Species groups	Number of species in the locality	Number of species in the agroecosystems	Prioritized species in production systems
Formative vegetal origin	2	2	Bean (*Phaseolus vulgaris* L.)
Formative animal origin	11	8	Cattle, horses, poultry, pig, goat, sheep, rabbit, beekeeping, fish, quail and turkey
Energetic (roots and tubers)	11	10	Cassava *(Manihot esculentum* Crantz.) Plantain (*Musa* spp.) Sweet potato *(Ipomoea batatas* L.) Malanga (*Xanthosoma sagittifolium* (L.) Schott)
Energetic (cereals)	2	1	Corn (*Zea mays* L.)
Energetic (oilseeds)	1	-	Sunflower (*Helianthus annuus* L.) as ornamental plant
Regulatory (vegetables)	13	10	Onions (*Allium cepa* L.) Tomato *(Solanum lycopersicum* L.)
Regulatory (fruit tree species)	23	11	Aguacate *(Persea americana* L.) Mango (*Mangifera indica* L.) Guava *(Psidium guajava* L.)
Total FER group	**62**	**42**	
Note: The species found in the ecological niches of the houses do not constitute commercial items because they appear in limited quantities, but they were recorded as contributions from the agroecosystems as a germplasm bank, indicators of the possibility of forming part of the systems.			

There was also a shortage in the agroecosystems of rice producers (Oryza sativa L.), however, they have another diversity of energetic species that can supply the bodily needs of that food, something that attacks consumption habits, although these consumption habits do not always favor human health or the agroecosystem.

The group animal feed FE (subindex IFE) included a total of five species, two of which are those that all farmers establish as energy foods: sugar cane (*Saccharum officinarum* L.) and King Grass (*Pennisetum purpureum* L.), which is apparently insufficient, according to the quantity and diversity of animals in the present agroecosystems (Table 3).

Table 3. Behavior and utility values of species for the sub-indices IFE, IAVA and ICOM.

Sub - index	Utility values	Number of species in the locality	Number of species in the agroecosystems	Prioritized species	Observations
IFE	Formative	3	1	Residues of *P. vulgaris;* weeds and arboreal and residues of creeping legumes	Incorporation of soybean (*Glycine max* L.) as a high priority specie for the locality
	Energetic	2	2	*Saccharum* spp. and *P. purpureum*	
IAVA	Soil protection	Weeds	Weeds	-	Lack of green manures. Only weeds are incorporated
	Water protection	1	1	River protection	Use of bamboo (*Bambusa vulgaris* Schrad. ex Went) on the river slopes.
	Improving air quality and counteracting the adverse effects of climate	Groves with perennial species	The number of desired tree species was calculated appropriately.	The specie *Cordia collococca* L. was recommended to incorporate due to its multipurpose functions.	60 % of species have a high carbon retention capacity and resilience to protect agroecosystems from adverse natural events.
ICOM	Conservation of free-ranging species of diverse utility	It was estimated that 60% of species were useful to the community	The number of desired tree species was calculated as adequate.	It was considered important to incorporate perennial species	Recommendation: grow of spices such as Laurel (*Laurus nobilis* L.) and Cinnamon (*Cinnamomum verum* J. Presl)

Protein species such as mulberry (*Morus alba* L.), moringa (*Moringa oleifera* Lam.), and titonia (*Tithonia diversifolia* (Helms.) A. Gray), have been introduced to the area, which is praiseworthy, but is still absent in most agroecosystems.

Within the species that make up the AVA group (subindex IAVA), it is not usual to use green manures to improve soil fertility despite the existence of some of them such as *Crotalaria juncea* L., *Sesbania rostrata* Bremek. & Oberm. and *Canavalia ensiformis* L., which have been well studied in Cuba (García Ramos, 1997).

The indicator that refers to the protection and conservation of the natural resource water has the bamboo cane established for the protection of the river slopes, which constitutes a plausible action; in addition, the local conditions themselves facilitate its natural reproduction and multiplication on its margins, which requires greater attention to periodic maintenance.

The diversity of species is sufficient in perennial trees that retain aerial carbon, to maintain greater purity of the air breathed in the locality, while the weed vegetation protects the soils of all agroecosystems. Which have not received herbicides for more than 15 years according to information from local actors and the Ministry of Agriculture, from 2023.

Species not included in the subgroups listed are included in the ICOM Subindex. In the locality, this subindex maintains an adequate species composition, even though there are necessary species absent in the agroecosystem and, due to the custom of acquiring them in the market, they do not have them in their homes.

Results of the Agrobiodiversity Index (IDA)

The IDA values of the agroecosystems were determined according to the value of the species diversity of each group. The calculations was carried out together with the leading authors and oscillate between 0.5 (IAVA) and 0.68 (IFER), (Table 4).

Table 4. Values of IDA of the ten Agroecosystems with their respective sub-indices during the research trajectory.

Subgroups	Components	Value of IDA
IFER	Food for humans	0,68
IFE	Food for animals	0,60
IAVA	Protection of natural resources	0,50
ICOM	Associated diversity of diverse non-food utility	0,66
IDA	**(IFER+ IFE+ IAVA+ ICOM)/ 4**	**0,61**

In observations after 2020, it was possible to confirm the existence of stability in the agroecosystems without increases in the FER, FE and AVA subgroups. The COM group has benefited from the increase in species associated with crops, given the impossibility of their timely management due to lack of resources.

Limitations to achieving sustainable IDA values (≥ 0.7) are given by deficiencies in the animal feed group of protein species in all agroecosystems; in addition, the absence of soybean cultivation, an essential protein grain, is a limitation and the scarce protection of the natural resource soil in the second, due to the lack of crops of green manure species.

However, the IFER and ICOM sub-indexes are closer to sustainability, all of which will be achieved from a practical point of view, with the introduction of some essential species into agroecosystems and multiplying others that exist locally but are scarce in agroecosystems.

Black bean varieties (*P. vulgaris*) was identified by local stakeholders as the main crop in the area due to its nutritional benefits, consumption habits and sales value in marketing processes. Among the most desired energy species, plantain was identified, followed by corn and cassava. In particular, malanga (*X. sagittifolium)* is widely used for feeding children by family tradition, while the short-cycle sweet potato completes the group of energy species.

In addition to the species listed above, vegetables are grown primarily under intensive family garden conditions. Intercropped within the perennial regulatory species which are planted as commercial crops, such as avocado *(P. americana*), mango *(M. indica*), guava (*P. guajava*)and papaya (*C. papaya* L.) are grown annual crops such as pumpkin (*C. maxima* Duchesne), zucchini (*Cucurbita pepo* L.) and cucumber (*C. sativus* L.) among others of short cycle convenient for the market.

Among the animal species that provide food with high protein content, cattle, poultry and pigs are the most sought-after species. Equines are mainly used for transport or as a substitute for agricultural machinery.

DISCUSSION

The results of the research showed that, starting in 2016, a gradual deleterious effect manifested in a change in the coherence of local agricultural development. The pace of use of space over time was affected by the scarcity of resources expressed in imported inputs and the lack of substitution alternatives at the local level, which were the fundamental causes, according to the vision of the most productive actors.

The diversity linked to human nutrition expressed through the IFER sub-index assumed the highest priority, but did not show significant changes to previous studies (Gravina Hernández & Leyva Galán, 2012; Martínez, 2019). The values of the IFER sub-index in 2016 were higher than those in other locations in Cuba (Leyva et al., 2000; González et al., 2018), where the number of reported species was 35% lower and without significant progress during the following years.

However, the greatest limitation of the group of species in the IFER subindex is the total absence of oleaginous species aimed at the local production of vegetable oil, which constitutes a big obstacle to achieving food sovereignty. A viable alternative is the sunflower that in previous times was, according to the criteria of long-lived actors, a species of high demand within the local trade and therefore the possibility of its successful production is known. This specie constitutes an opportunity that should be assumed for its benefits as an oilseed species with about 50% oil in grain and high protein content in the biomass, recommended as animal feed. Furthermore, on the other hand, unlike other grains such as soybeans (*Glycine max* L.), the oil extracted by pressing can be consumed by humans without refining, as it does not have strong odors and this technology is known in Cuba, for work carried out within the Urban Agriculture movement in Cuba (Betto, 2021).

The scarce presence of rice (*Oryza sativa* L.), one of the highest priority caloric foods in the local diet (González-Viera et al., 2022), absent in nine of the ten agroecosystems is justified by the lack of resources to bring water from the river to the crops. Together with the existence of only one plant-based food-forming species (P. vulgaris), are two weaknesses in achieving Food Sovereignty. Although the stability of the index is not affected, since both deficiencies are replaced by other food options that maintain the stability of the index with the necessary recommendation to include new species, especially plant-based forming species.

To increase the resilience capacity of the plant-based protein component, it will be necessary to incorporate different legume species after knowing the species with the highest demand. It is curious that black beans are consumed so widely by the Cuban population, unlike in Latin American countries, where the diversity of consumption of other protein grains is greater (Leyva Galán, 2022)

There is still no favorable relationship between the species existing in the agroecosystems and the desired diversity, which would allow the sustainability of agrobiodiversity according to the rigors of the IDA index. The solution will depend on the elaboration and management of a prospective development program that can restore the agroecosystems of the Mena community, following the suggestions that have emerged as a result of this research. Species in high demand, such as potato (*Solanum tuberosum* L.) and coffee (*Coffea arabica* L.), have lost their historical imprint. While the first is not currently cultivated, the second was only found in two agroecosystems without adequate technical attention. Within the perennial species of the group of regulators with sporadic presence, the red mamey (*Calocarpum sapota* Jacq.), citrus in general and Annonaceae were identified among the fruit trees. Their importance should be considered in the face of emerging tourism near the locality.

Flowers were a high-demand commercial item that has now disappeared. However, this requires a specific study to identify potential families motivated to recover this tradition, beyond the necessary promotion of traditional gardens typical of the family environment.

The development of this productive item can constitute the basis of a possible marketing mechanism towards the nearest city and for the tourist sector present just a few kilometers from the town.

Finally, and as an essential complement to the process of preparing food and medicines on a local scale, attention must be paid to the production of various species to maintain the health of the inhabitants in optimal conditions from a human spiritual perspective, the production of plants for spices and medicines must be attended to with greater rigor.

CONCLUSIONS

1. The Mena community of the Yumurí Valley has a rich agrobiodiversity, which generally meets the food needs of the locality and the study made it possible to detect the corrections that will be may have sustainability from agrobiodiversity through the application of the IDA index.
2. The application of the Agrobiodiversity Index (IDA) facilitated the evaluation process and was understood by local actors for future assessments without the presence of external facilitators, which opens the way to a new methodology for the diversification of local agroecosystems in any region that aspires to agroecological sustainability.
3. It is worth highlighting the fact that they have a high diversity of protein production of animal origin, something that is not typical in Cuba. This diversity with optimal levels of production constitutes an experience of excellent significance for the development of other localities in Cuba.
4. It would be advisable to make the results of this research known to the local community in the presence of actors, decision-makers and facilitators in order to initiate a process of comprehensive restoration of local agrobiodiversity, in favor of prospective agroecological agriculture.

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