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ASSESSMENT OF THE SUSTAINABILITY OF AGRICULTURAL AND LIVESTOCK PRODUCTION SYSTEMS

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ABSTRACT

Consolidating the peace process in Colombian territory requires determining the relevance of the agricultural and livestock production systems promoted by national and international organisms as an economic alternative in the reincorporation of Revolutionary Armed Forces of Colombia (FARC) ex-combatants. Such is the case with the systems proposed in the Nueva Colombia (New Colombia) farm, located in the Pondores area of the Fonseca municipality in La Guajira, Colombia. In order to answer the question “Are the production systems of the Nueva Colombia farm sustainable?”, we carried out a qualitative agroecological assessment of five systems used (maize [*Zea mays* L.], cassava [*Manihot esculenta* Crantz], plantain [*Musa* x *paradisiaca* L. var. Hartón], cattle ranching, and poultry farming). Producers, technical consultants, and researchers participated in the assessment, with the goal of establishing a viability baseline and criteria to determine the convenience of allocating resources for the continuity of the systems. The results show that the Nueva Colombia farm is located in a very dry tropical forest life zone. The assessment shows moderate sustainability for plantain and cassava crops and weak sustainability for maize. As for the animal production systems, it was found that cattle ranching is not a sustainable system and that, therefore, its operation is not viable, while poultry farming is moderately sustainable. We concluded that it is not advisable to continue cattle production, and that the resources should be reallocated towards improving the poultry farming system. The agricultural systems require the implementation of practices that increase the specific and spatial diversity of crops, as well as their stress tolerance and the proportion of organic matter in soil.

Keywords: sustainability indicators, agroecological assessment, participatory diagnosis.

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INTRODUCTION

The concept of sustainability has become associated with integrated spatial planning and governance on a local and global scale. This approach depicts an idea of socioeconomic development in which political, economic, and social activities are integrated in harmony with the environment and natural processes in order to ensure the fundamental needs of society for both current and future generations (Ogryzek, 2023). Governance implies different actors reaching consensus on decision-making regarding the implementation of public policies applied to the territory (Campo-Ramírez, 2022).

Making decisions on the suitability and selection of better crops or livestock production alternatives requires an assessment of the production systems (Marcis *et al*., 2019). This requires rapid assessment methodologies, since, in practice, assertive decisions must be taken within time constraints, such as those imposed by new forms of social and economic organization conceived within the territories. These decisions must also consider the transition to a new farmer centered agricultural system structure (Iakovidis *et al*., 2022).

Agroecosystem sustainability reflects compliance with agroecological requirements on any farm, regardless of the differences that production systems may have in their management, economic level, landscape position —among others— and how they compare over time (Altieri and Nicholls, 2002). The assessment of agroecosystem sustainability allows for the determination of the management needs of each system in order to maintain or improve productivity, reduce risks and uncertainty, protect the resource base, and prevent soil, water, and biodiversity degradation (Altieri, 1997).

In order to assess agroecosystem sustainability, indicators that allow for the measurement and comparison of each agroecosystem over time are developed through a participatory process (Altieri and Nicholls, 2002). Several researchers have designed sustainability indicator systems for specific conditions and ecosystems. Unfortunately, few of them are producer friendly. As a result, Nicholls *et al*. (2004) propose the participatory creation of indicators as a type of rapid and producer-friendly assessment.

The Nueva Colombia (New Colombia) farm is one of the sites used by former combatants of the now extinct FARC-EP for agriculture and livestock production. It is located in the Pondores area of the Fonseca municipality in La Guajira, Colombia. In an effort to contribute to the social and productive reincorporation of this population, different agricultural production initiatives have been proposed. Their viability must be evaluated to ensure both long-term sustainability and the contribution of these initiatives to a successful reincorporation process.

To answer the question "Are the agricultural production systems of the Nueva Colombia farm sustainable?", this work aimed to establish a sustainability baseline for the production systems currently operating at the farm (maize [*Zea mays* L.], cassava [*Manihot esculenta* Crantz], plantain [*Musa* x *paradisiaca* L. var. Hartón], cattle ranching, and poultry farming). Indicator-based assessment allows for the establishment criteria for making swift decisions about the feasibility of implementing a productive system, as well as the definition of a baseline and the formulation of actions to improve the sustainability of alternative production methods.

MATERIALS AND METHODS

This study follows a qualitative and descriptive methodology. A participatory diagnosis methodology was implemented via an assessment instrument for the validation and scoring of indicators. The study was conducted at the Nueva Colombia farm, which is located in the Pondores area of the municipality of Fonseca in the department of La

Guajira, Colombia (10° 46′ 21″ N, 72° 47′ 20″ W), with an altitude of 220 m. The life zone of this farm is classified as "very dry tropical forest," which, according to the Holdridge (2000) classification, are tropical latitudinal regions with rainfall between 500 and 1000 mm per year and average temperatures above 24 °C.

The farm has a total area of 198.33 ha for agricultural and livestock activities in which 15 ex-combatants work. We assessed plantain (*Musa* x *paradisiaca* L. var. Hartón) (7 ha), cassava (*Manihot esculenta* Crantz) (1 ha), and maize (*Zea mays* L.) (2.4 ha), which are grown on the flatter area of the property. The soil has a loose sandy loam texture, is fairly deep, and is composed of alluvium with a low organic matter content. Water supply is subject to seasonal rainfall.

The plantain crop was fertilized with 15-15-15 (NPK) fertilizer without fungicide applications for sigatoka control. The crops were watered through a gravity irrigation system and rainfall, but the prolonged dry season in the region caused stunted growth, bent pseudostems, and low-yielding bunches. Maize was cultivated using a minimum tillage model interspersed with shrubs and certain weeds, reclaiming traditional knowledge. In cassava cultivation, practices such as the application of chemical fertilizers and small adaptations of agroecological practices were used.

The poultry farming system consisted of a free-range chicken system with production from grazing laying hens. There was a total of 800 Hy-Line Brown birds in their 22nd week of laying, with a central coop surrounded by pasture for animal grazing. The system had access to technical consultancy, and the birds were mainly fed with balanced feed. The cattle ranching system consisted of a herd of 30 commercial Zebu cattle, 5 dairy cows, 10 weaned animals, and 4 nursing female calves, all managed under a traditional extensive cattle system with little or no pastureland renewal.

The assessment took place between the second half of 2018 and the first half of 2019, with the participation of 21 people: 15 producers, 3 technical assistants, and 3 researchers. The methodology was divided into four stages: (1) education sessions to bring producers together, technical assistants from cooperating agencies and researchers, and the presentation of the assessment's purpose and methodology; (2) participatory creation of the indicators; (3) participatory measurement; and (4) analysis of the indicators as a whole to reach conclusions on the sustainability of the evaluated systems.

When developing the indicator system, two factors were considered: (a) the indicators should be user friendly for the various parties, particularly for producers and technical assistants, and (b) they should be able to be scored quickly by consensus among the three involved parties, including the researchers. Each indicator received a score ranging from 1 to 10, with a score of less than 5 indicating weak sustainability, 5–8 showing moderate sustainability, and a value greater than 8 indicating strong sustainability. The value of each indicator was calculated by averaging the scores of the 21 participants who took part in the assessment.

After scoring the indicators, the information was processed and organized into radar charts, which the parties analyzed in workshops. The consolidated information was used to share the baseline with the directors of the organization and was also used in the selection, prioritization, and development of system management strategies. Two attributes were used in the assessment of the agriculture systems: (a) soil quality, including pastures for the cattle ranching system; and (b) crops (Nicholls *et al*., 2004). Ten indicators were defined for analyzing soil quality (Table 1).

Eleven indicators were selected for crop assessment (Table 2).

Table 1. Indicators for soil quality assessment in the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

Indicator	Values	Characteristics
Structure	Less than 5	Powdery soil without visible aggregates
	5–8	Few aggregates that break at low pressure
	Greater than 8	Well-formed aggregates that are difficult to break
Compaction	Less than 5	Compacted soil, wire bends easily
	5–8	Thin compacted layer, some resistance to a penetrating wire
	Greater than 8	No compaction, the wire fully penetrates the soil
Depth	Less than 5	Exposed subsoil
	5–8	Thin surface soil, 1–10 cm
	Greater than 8	Soil depth greater than 10 cm
Organic residues	Less than 5	Slow decomposition of organic residues
	5–8	Presence of decomposing residues from the last year
	Greater than 8	Residues in various stages of decomposition, most of it is well decomposed
Color, odor, and organic matter	Less than 5	Pale, chemical odor, and no presence of humus
	5–8	Light brown, odorless, and with some presence of humus
	Greater than 8	Dark brown, fresh odor, and abundant humus
Infiltration rate after irrigation or rainfall	Less than 5	Very low: soil remains waterlogged after heavy rain, significantly affecting the crops
	5–8	Medium: soil becomes waterlogged after heavy rain, but crops are only slightly affected
	Greater than 8	High and adequate: no waterlogging after heavy rain
Vegetation cover	Less than 5	Bare soil
	5–8	Less than 50 % of the soil with vegetation cover
	Greater than 8	Over 50 % of the soil with vegetation cover
Erosion	Less than 5	Severe erosion, presence of small cracks
	5–8	Clear signs of erosion
	Greater than 8	No visible signs of erosion
Presence of invertebrates	Less than 5	No signs of invertebrate presence or activity
	5–8	Some earthworms and arthropods present
	Greater than 8	Abundant invertebrate organisms present
Microbiological activity	Less than 5	Very little effervescence after application of hydrogen peroxide
	5–8	Slight to medium effervescence after application of hydrogen peroxide
	Greater than 8	Abundant effervescence after application of hydrogen peroxide

Adapted from Nicholls *et al*. (2004).

Table 2. Indicators for crop assessment in the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

Indicator	Values	Characteristics
Appearance	Less than 5	Chlorotic and discolored foliage with signs of deficiency
	5–8	Light green foliage with slight discoloration
	Greater than 8	Dark green foliage, no signs of deficiency
Crop growth	Less than 5	Uneven support, short and thin branches, limited new growth
	5–8	Denser, uniform support, thicker branches, with new growth
	Greater than 8	Abundant branches and foliage, vigorous growth
Incidence of disease	Less than 5	Susceptible, more than 50 % of plants present damaged leaves and/or fruit
	5–8	25–45 % of plants presenting damage
	Greater than 8	Resistant, less than 20 % of plants with slight damage
Incidence of pests and insects	Less than 5	More than 15 insect nymphs per leaf, or more than 85 % of leaves damaged
	5–8	5–14 insect nymphs per leaf, or 30–40 % of leaves damaged
	Greater than 8	Less than 5 insect nymphs per leaf, or less than 30 % of leaves damaged
Plant genetic diversity	Less than 5	Monoculture
	5–8	Uneven cover crops or spatially dispersed productive species
	Greater than 8	Dense cover crops and other crops occupying more than 40 % of the area
Surrounding natural vegetation	Less than 5	Surrounded by other crops, without natural vegetation
	5–8	Adjacent to natural vegetation on at least one side
	Greater than 8	Surrounded by natural vegetation on at least two sides
Yield	Less than 5	Low in relation to the local average
	5–8	Medium, acceptable considering the local average
	Greater than 8	Good or high in relation to the local average
Dependency on external supplies	Less than 5	More than 60 % of supplies are external to the system
	5–8	30–59 % of supplies are produced within the system
	Greater than 8	More than 60 % of supplies are produced within the system
Family benefit (self-consum-ption)	Less than 5	Most of the produce is marketed outside the system
	5–8	Up to 40 % of produce is for self-consumption due to low market prices
	Greater than 8	At least 40 % of produce is for family consumption
Water quality and availability	Less than 5	Periods of long-lasting water shortages with major impacts
	5–8	Water shortages at certain times of the year, but without severe impacts
	Greater than 8	Sufficient for cultivation and other farm needs
System management	Less than 5	Conventional with green revolution technology
	5–8	Transitioning to organic and to substituting agrochemicals
	Greater than 8	Organic, diversified with little external supplies

Adapted from Nicholls *et al*. (2004).

To determine the indicators for livestock systems, the methodological proposal developed by Cruz *et al*. (2018) was used. Their proposal was designed to assess the sustainability of Colombian cattle ranching systems in the lower Negro River basin. This methodological proposal is based on an adaptation of the Framework for Evaluating Natural Resource Management Systems Incorporating Sustainability Indicators (Marco para la Evaluación de Sistemas de Manejo de Recursos Naturales Incorporando Indicadores de Sostenibilidad, MESMIS) (Arnés and Astier, 2018). The authors defined eight indicators for the assessment of livestock farming systems (Table 3).

Table 3. Indicators for livestock assessment in the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

Indicator	Values	Characteristics
Incidence of disease	Less than 5	Presence of disease with over 10 % mortality
	5–8	25–45 % morbidity and 3–10 % mortality
	Greater than 8	Resistant, morbidity and mortality do not exceed 3 %
Animal genetic diversity	Less than 5	Breeding of a single breed or genetic line
	5–8	At least two breeds or genetic lines are used
	Greater than 8	More than two are used, with the inclusion of native breeds or genetic lines
System management	Less than 5	Conventional
	5–8	Transitioning to organic or with substitution of external supplies
	Greater than 8	Organic, diversified with little external biological supplies
Surrounding natural vegetation	Less than 5	Surrounded by other crops, without natural vegetation
	5–8	Adjacent to natural vegetation on at least one side
	Greater than 8	Surrounded by natural vegetation on at least two sides
Yield	Less than 5	Low in relation to the local average
	5–8	Medium, acceptable considering the local average
	Greater than 8	Good or high in relation to the local average
Dependency on external supplies	Less than 5	More than 60 % of supplies are external to the system
	5–8	30–59 % of supplies are produced within the system
	Greater than 8	More than 60 % of supplies are produced within the system
Family benefit (self-consum-ption)	Less than 5	Most of the produce is marketed outside the system
	5–8	Up to 40 % is for self-consumption
	Greater than 8	At least 40 % of produce is for self-consumption
Water quality and availability	Less than 5	Periods of water shortages with major impacts on yield
	5–8	Shortages at certain times of the year, but the impact is not severe
	Greater than 8	Sufficient for animals and other farm needs

Adapted from Cruz *et al*. (2018).

RESULTS AND DISCUSSION

Assessment of agricultural systems

Soil quality exhibits critical indicators in terms of biological activity, infiltration rate, and structure. The average of the indicators for the plantain crop was 7, showing moderate sustainability. Maize yielded an average of 3.5, indicating weak sustainability levels. It is especially weak in biological activity, which is related to low organic residues due to low organic matter content. As for cassava, an average of 5.2 was reported, indicating a moderate level of sustainability, mainly as a result of low biological activity. The pasture soil used for cattle ranching presented weak levels of sustainability, with a total average of 3.4. This result was mainly due to structure indicators and the presence of stoniness limiting the penetration of pasture roots, as well as low biological activity (Figure 1).

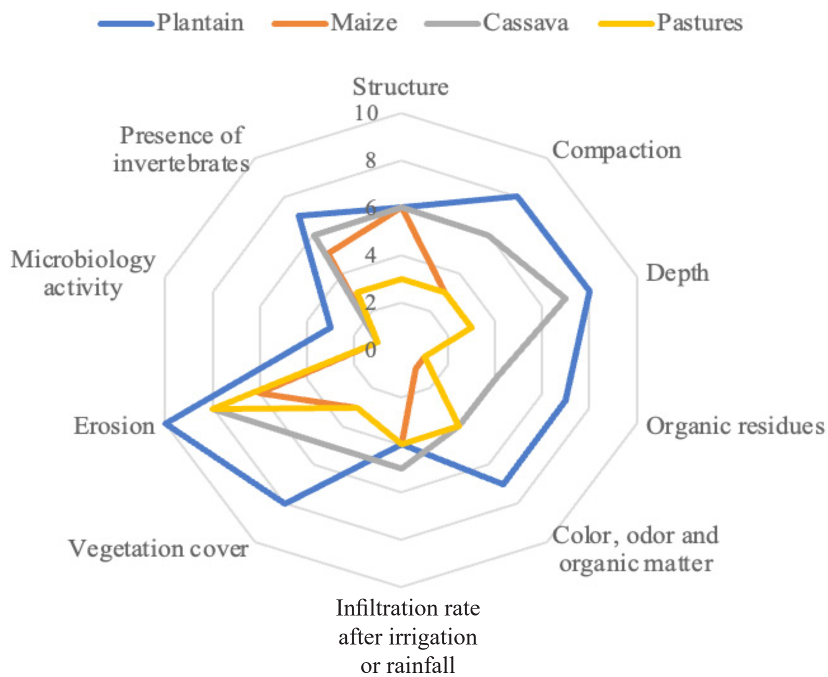

Figure 1. Assessment of the soil quality indicators in the plantain crop (*Musa* x *paradisiaca* L. var. Hartón), maize (*Zea mays* L.), cassava (*Manihot esculenta* Crantz) and pastures in the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

The infiltration test conducted in the maize field during the low rainfall period showed a rapid decrease in the water level during the first 300 s (Figure 2a). This is further confirmed by analyzing the infiltration rates (Figure 2b), which average 71 mm s^{-1}

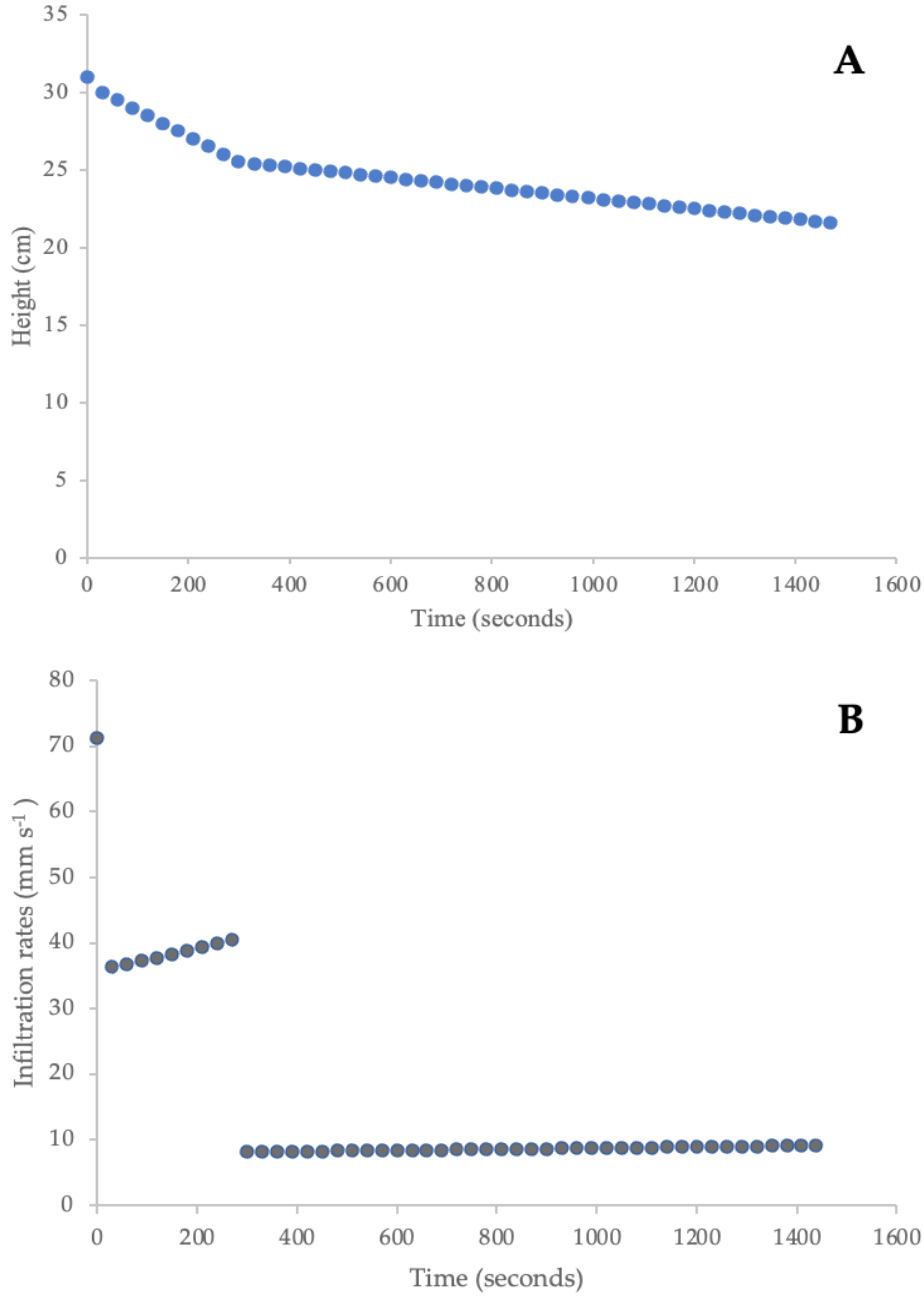

Figure 2. Soil infiltration rates in the Nueva Colombia farm, Fonseca, La Guajira, Colombia. A: drop in the water level at the time of evaluation; B: Infiltration rate of water into the soil (mm s^{-1}).

in the first moments of the test before decreasing to a rate ranging between 36.3 and 40 mm s^{-1}. High initial infiltration rates occur due to sorptivity, but as time passes, the infiltration rate settles to a constant value, known as basic infiltration, which is similar to saturated hydraulic conductivity (Rodríguez-Vásquez *et al*., 2008). In the assessed soil, after 300 s, the rates stabilized at values between 8–9 mm s^{-1}, as posited by Rodríguez-Vásquez *et al*. (2008).

The surrounding natural diversity stands out in the crop assessment, as all crops are surrounded by native forest and recovering fallow land, and there is good plant and bird diversity. Therefore, all crops scored 10 on this indicator. According to Nicholls *et al*. (2004), a production system surrounded by natural vegetation favors sustainability and ecological interactions that provide greater pest resistance (Altieri and Nicholls, 2018). At the opposite end of the spectrum is the specific and spatial genetic diversity indicator for crops, with values of 2 and 5 for cassava and plantain, respectively. Producers opt to transition from monoculture systems to more diversified and organic systems in order to achieve production stability without depending on external resources while preserving valuable resources, such as soil, water, and biodiversity (Nicholls *et al*., 2015).

The same variety was planted for the entire maize crop, but it was cultivated by using minimum tillage. This included having a spatial distribution of weeds and tree cover, which was a practice used by the ex-combatants in the Colombian jungle. Therefore, the specific and spatial diversity indicator score was 7 in this case, as it retrieves traditional cultivation knowledge and adapts it to conservation production models. This demonstrates the importance of incorporating local traditional knowledge, which has been developed and perfected by producers over several generations (Altieri and Nicholls, 2002). In general, these types of knowledge allow productive enterprises to better adapt to local and sustainable conditions.

The design and assessment workshops revealed an evident water supply issue. For this indicator, the plantain, maize, and cassava crops all scored below the sustainability threshold, with values of 3, 4, and 4, respectively. These figures reflect the reliance on the rainfall system and a small irrigation system using water from a stream that dries up during the dry season. The assessment conducted during the dry season in March 2019 provided additional confirmation of this. It revealed that the crops suffered significant damage due to a shortage of irrigation water. This finding was the basis for the decision to halt the plantain crop (Figure 3).

As for the management system, maize is cultivated using a minimum tillage model interspersed with shrubs and weeds, reclaiming traditional knowledge. This is in contrast to the plantain and cassava crops, which are grown using chemical fertilizers and small adaptations of agroecological practices. To improve the overall sustainability of the agroecosystem, it is necessary to prioritize actions on soil and crop quality attributes with weak sustainability levels. Intervention on one important attribute can lead to the correction of others as a result. For example, increasing the level of soil organic matter can also help improve water storage capacity, soil biological activity, soil structure, and nutrient availability (Altieri and Nicholls, 2007).

Assessment of livestock systems

Other indicators were used for the assessment of the animal production systems, since rapid assessment methodologies focus mainly on agricultural systems (Agossou

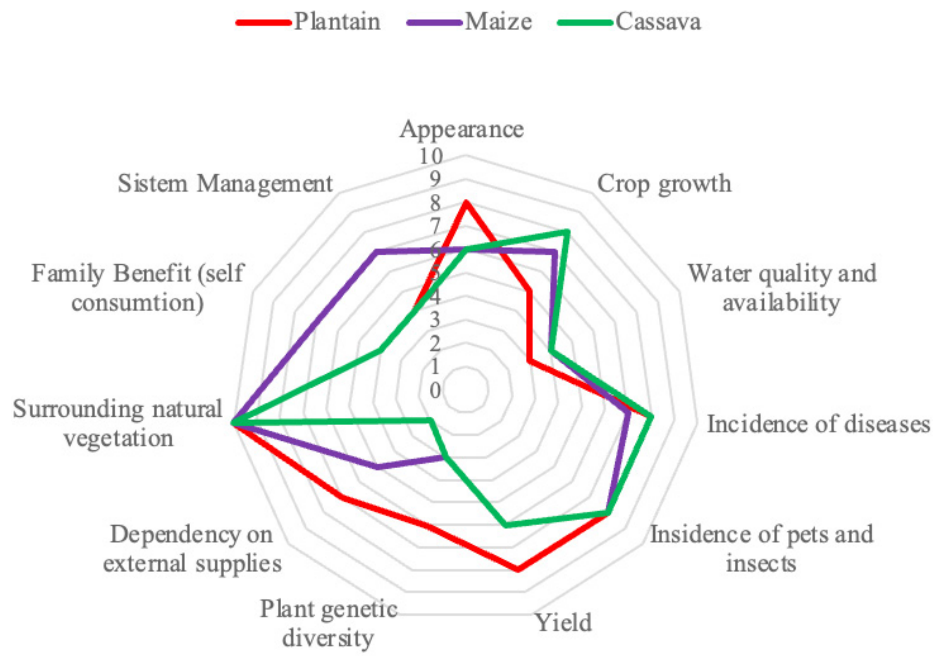

Figure 3. Crop assessment in the plantain crop (*Musa* x *paradisiaca* L. var. Hartón), maize (*Zea mays* L.), and cassava (*Manihot esculenta* Crantz) in the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

et al., 2017; Abou *et al*., 2018; Faye *et al*., 2020). Here, poultry farming showed strong sustainability, especially for indicators associated with bird well-being. The environment is surrounded by trees that mitigate high temperatures by providing shade and comfort, allowing birds to wander and forage.

Family benefit (self-consumption) and genetic diversity were found to be weakly sustainable. The former, although subject to improvement, shows the contribution to the diet of the families linked to the Nueva Colombia farm and constitutes a model that can be easily replicated or expanded. It is feasible to increase the production volume to meet the needs of the population of the farm and its area of influence, resulting in a higher income. In terms of genetic diversity, there is only one line of commercial laying hens, an indicator that could be improved by incorporating native breeds that perform well in these areas of production (Figure 4).

Most of the indicators of the cattle ranching production system were found to be below the sustainability threshold. The circumstances surrounding this activity call for immediate action. The low scores for indicators such as livestock yield and system management originate in the extensive production model, which has a very low stocking rate and inadequate or non-existent soil and pasture management. Therefore, the development of this production system is not recommended (Figure 4).

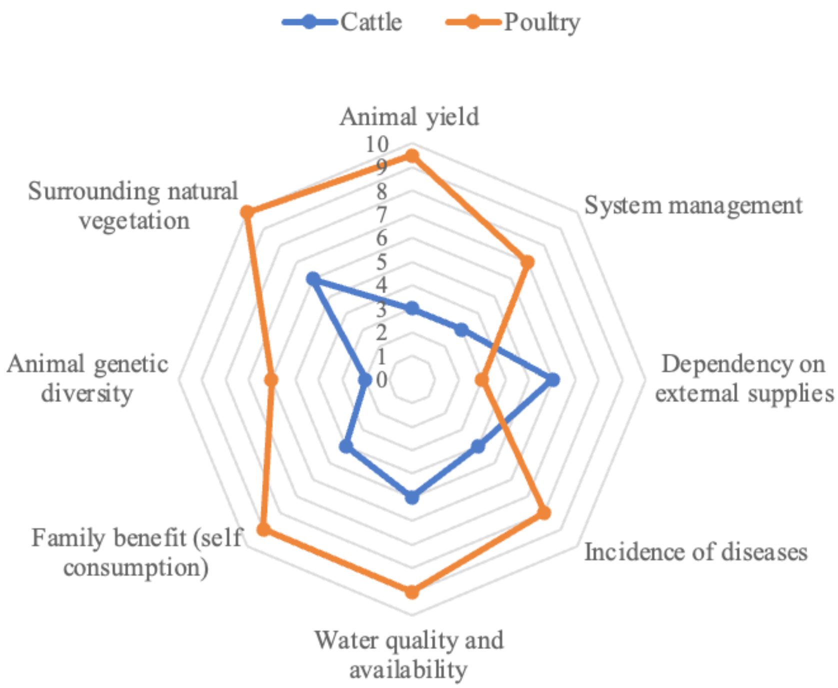

Figure 4. Assessment of the animal production systems in the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

In the case of cattle ranching, the weak sustainability assessment is explained by the extensive cattle ranching model that has prevailed in Colombia. According to Molina-Benavides *et al*. (2020), the cattle inventory in the country is close to 23 million animals spread across 39 million ha, with an average stocking rate of 0.6 animals per ha^{-1}. This stocking rate has not changed significantly in the last twenty years, which reveals the low technological transformation of the livestock sector. The production cooperative started its livestock farming system with a traditional approach, which is reflected in the level of sustainability found.

Sustainability of production systems

On average, none of the production systems showed strong sustainability. Plantain and cassava crops, as well as poultry farming, showed moderate sustainability, while maize and cattle ranching showed weak sustainability (Table 4).

The assessment led to the development of the baseline for sustainability indicators. By using it, it will be possible to observe changes over time resulting from the modifications to the different components of the production systems. These changes will be analyzed in the periods that the directors deem convenient, preferably on a semi-annual or annual basis. Authors such as Pope (2006), Coteur *et al*. (2016), and Coteur *et al*. (2020) highlight the importance of the application and use of sustainability indicators in decision making for agricultural and livestock companies. Sustainability

Table 4. Sustainability levels of the production systems of the Nueva Colombia farm, Fonseca, La Guajira, Colombia.

	Plantain (*Musa* x *paradisiaca* L. var. Hartón)	Maize (*Zea mays* L.)	Cassava (*Manihot esculenta* Crantz)	Poultry	Cattle
Average value of sustainability indicators	6.8	4.9	5.5	7.7	4.1

assessment allows us to identify the strengths and weaknesses of agricultural and livestock systems understood as productive businesses.

Following de Olde *et al*. (2016), evaluating indicators at the farm level has several purposes, of which the following stand out: (a) as a tool to promote the sustainable development of farms, and (b) as a way to inform medium and long-term decision making regarding the continuity of systems and/or the significant changes required to improve the sustainability of production systems. Strategies for the integration of the agricultural and livestock systems were proposed for the three moderately sustainable systems. These include using crop products and by-products (cassava and plantain) to feed laying hens —which reduces the dependency of this system on external supplies—; using excreta from livestock systems to produce fertilizers through composting, reducing the use of synthetic fertilizers; promoting family consumption of agriculture and livestock products to improve the diets of producers; selling animals or animal produce for cash to purchase agricultural products, or, conversely, selling agricultural products to withstand periods of lack of liquidity in livestock systems. All these synergetic interactions have been extensively discussed by authors such as Witjaksono *et al*. (2018).

Although the sustainability assessment for maize was weak, the importance of recovering the minimum tillage cultivation method was recognized, as it saves the valuable experience of many years of cultivation in the Colombian jungle. Therefore, improvement strategies were proposed, including the utilization of knowledge regarding the advantages and drawbacks of the farm's soils for organic fertilization and the use of chicken manure obtained from the poultry farming system. These strategies seek to rescue local knowledge and to integrate it with regenerative agriculture practices, resulting in a production geared toward self-consumption.

The lack of high levels of sustainability in the evaluated agricultural systems highlights the importance of incorporating prior assessments into decision-making processes related to project financing by national and international cooperative organizations. Participatory diagnosis provides producers with criteria for: (a) defining the continuity of systems; (b) better targeting available and/or future resources from new forms of national and international cooperation; and (c) raising awareness on the urgency of incorporating sustainability dimensions into the assessment of production systems. Similarly, Iakovidis *et al*. (2022) argue that sustainability assessment systems improve understanding of economic and social dynamics. This knowledge supported the development of strategies aimed at improving the production systems under evaluation.

In general, sustainability indicators are developed by scientists and expressed in technical language. However, it is recommended that the beneficiaries participate in the conceptualization and development of indicators. This increases the likelihood that they use these indicators and value their results (Cruz *et al*., 2018). The results achieved during the workshops for the development of the indicator system—seeking that all parties understood it—not only permeated within the production cooperative, but also helped the cooperating agencies' technical assistants recognize the benefits of sustainability and know more about it, particularly how to assess it in practice. The project researchers also recognized the importance of collective construction, improved their skills for participatory work, and learned about ways of integrating ancestral and local knowledge with scientific and technological knowledge.

CONCLUSIONS

Access to water is a critical issue for the long-term viability of the Nueva Colombia farm's production systems in the municipality of Fonseca, La Guajira. Therefore, a deep well and an irrigation system must be implemented. A baseline for the sustainability of the farm's production systems was established as an instrument to make decisions on their continuity or improvement. This will be achieved through practices that contribute to the conservation and adequate management of the region's natural resources.

The plantain and cassava crops show moderate sustainability and reveal the need to increase biological interactions, optimize the use of resources, create synergies, favor microclimates, generate habitats for local species, and increase productivity and profitability. Cassava crop sustainability is weak due to the low quality of the soil. Therefore, its continuity depends on the implementation of practices that increase organic matter and biological activity. As for the animal production systems, our results indicated that cattle ranching is not a sustainable system and therefore its operation is not viable, while poultry farming is moderately sustainable.

Participatory diagnosis allowed those in charge of production systems to become aware of the importance of the management and conservation of natural resources and to perform various actions in that regard, such as the conservation of forest areas, the promoting of native forest recovery in different parts of the production system, as well as the development of strategies for obtaining and conserving water resources. This assessment provides, in addition to a baseline, a methodology for monitoring production systems to ensure their sustainability.

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