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Research article

Analysis of recent land management initiatives in Nicaragua from the perspective of the "ecosystem approach"

William Muñoz *, Carla Garcia-Lozano, Diego Varga, Josep Pintó

University of Girona, Spain

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ABSTRACT

In the world there are approximately 608 million farms, of which 84% are small farms and produce 35% of the food of the world population. Training programs have been promoted by different organizations to achieve a more sustainable and efficient agricultural practice.

Within this context, this article has classified a set of smallholders located in central Nicaragua with regard to how they apply Land Use Management Initiatives (LUMI). The aim is to outline their weaknesses and strengths and thus identify key elements that can contribute to improving soil resource management. We focus on the LUMI carried out in Nicaragua in the municipalities of El Tuma-La Dalia, El Cuá and Waslala between 1992 and 2022.

To conduct this study, eight LUMI were identified and analysed, and 25 indicators linked to the Malawi Principles were extracted and selected for the design of a survey in order to collect land use management information from 455 farms in the study area. Simple random sampling was used to select the farms. Subsequently, the collected data were analysed using descriptive statistics and Multivariate Analysis techniques.

The results reveal that in the study area, the LUMI incorporate between one and five Malawi Principles. The multivariate analysis techniques employed identified three clusters of farms, with either Active, Moderate or Improvable ecosystem management. The study area as a whole displays strengths in social participation, local capacity building, soil and environmental conservation practices, with the farm as the main source of income. Weaknesses lie in the fact that indicators referring to household income and productivity are less frequent. In terms of farm management, the results revealed that combined male and female management was similar in percentage to male-only management.

The results highlight the need to continue with the implementation of environmental goals linked to the design of initiatives that promote productivity, income and gender equity in farm management in an integrated manner. At the same time, existing local capacities for sustainable soil and ecosystem management should be brought together and strengthened.

1. Introduction

In the world, there are about 608 million farms, and 84% of them are small farms (<2 ha), contributing to 35% of the world's food production (Lowder et al., 2021). Many of these small farmers face challenges that harm both their economic well-being and the environment. They are vulnerable to climate and environmental risks and often lack the necessary resources for their farm development. To increase their income, some resort to deforestation for more land (Dias et al., 2021). However, in recent decades, international organizations, NGOs, and national institutions have initiated training programs and various efforts to encourage small farmers to adopt more sustainable agricultural practices (Gumbi et al., 2023).

Regarding the situation in Latin America, Berdegué and Fuentealba (2014) estimate that there are 15 million family farms that control nearly 400 million hectares. Three quarters of which are subsistence farms or farms that face notable constraints due to the limitations of their assets and the context in which they operate. According to Ren et al. (2019), farm size has a substantial influence on agricultural sustainability from an economic, social and environmental perspective.

Nicaragua is an agricultural country that pursues food security for the population. The National Plan to Fight Poverty-(PNLCP, 2022)

* Corresponding author.
E-mail address: william.munoz@udg.edu (W. Muñoz).

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indicates that smallholders produce more than 80% of the food consumed by the population in the country. However, it is estimated that farmers on small farms (<5 ha) represent 60% of the country's total farms, although only 20% of the total agricultural land area (FAO and GEF, 2023). Large farms (50–350 ha) are linked to palm and sugar cane crops. These two crops are uncommon on small farms.

Production, food security and sustainable land use are interrelated and are essential aspects for the well-being of the Nicaraguan population. Despite the efforts made in terms of sustainability, reaching the optimal threshold of productivity and food security, based on sustainable land use, is a pending task in environmental management in Nicaragua. This is because the design of management processes does not take in account the threshold or resilience of natural resources (MARENA, 2017, 2020a, 2020b).

Over the years, various efforts to address these issues have been made through land use management initiatives (LUMI). These initiatives involve collaboration among universities, research centers, government programs, external partnerships, civil society organizations, and peasant cooperatives at different levels - international, regional, national, and local. The historical development of these initiatives dates back to before the 1970s, with significant milestones in their implementation at the farm level. However, this study focuses on the period from 1994 to 2022 due to a lack of systematic records before these dates. Importantly, there has been no centralized coordination by any administrative office with a comprehensive vision for the needs of Nicaraguan peasants. Instead, each initiative has been implemented independently, at different times, and in response to emerging needs.

At the Central American level, strategies for Risk management (SICA, 2006), Water Resources (SICA, 2009a) and Territorial Rural Development (ECADERT, 2010) were designed. The national level saw the Biodiversity Strategy (MARENA, 2015), Risk Management (SINAPRED, 2020) and the Water Law incorporated the need of River Basin Management (Gaceta, 2007). In parallel, agroforestry has promoted social, economic and environmental components and river basin management incorporated the principles of sustainable development (Muschler and Bonnemann, 1997; Faustino and Jiménez, 2000; Muschler, 2015). Agroecology is institutionally recognized in Nicaragua (Fréguin-Gresh, 2017; Gonzálvez et al., 2015). Complementarily, the sentinel landscape was studied (Sepúlveda et al., 2020).

In summary, the LUMIs implemented in small farms in Nicaragua between 1994 and 2022 promoted: i) Biodiversity conservation; ii) Territorial Development; iii) Landscape conservation; iv) Agroecology; v) Agroforestry; vi) Comprehensive management of water resources; vii) Comprehensive management of hydrographic basins and viii) Risk management in the face of natural disasters naturales (Villanueva et al., 2012).

However, many of the socioecological problems that were intended to be solved remain today. For this reason, this work aims to analyse to what extent the management initiatives implemented throughout the years have applied the Ecosystem Approach (EA), since that is a conceptual and methodological framework that has been adopted by different international conventions and agreements (Andrade et al., 2011). Among them UNESCO (Hadley, 2000), which includes it as a framework for the management of Biosphere Reserves; the FAO Fisheries Committee; the Commission on Genetic Resources for Food and Agriculture of the FAO, in 2007, etc. The EA has also been one of the conceptual pillars of the Millennium Ecosystem Assessment, carried out in 2005, in which it is explicitly recognized that humans and their cultural diversity are an integral component of ecosystems (UNEP, 2006).

The Ecosystem Approach was defined as a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way (CBD, 2000). To apply the Ecosystem Approach to land-use management, it is essential to incorporate the internationally renowned Malawi Principles (MP) for ecosystem-based management (CBD, 1998) (Supplementary Material 1). They include both natural and socio-economic concerns as well as participatory decision-making involving scientific and local knowledge.

Waylen et al. (2013), argue that committing to achieving effective, equitable and holistic resource management involves adopting the *ethos* of all the Malawi Principles (MP) and addressing the challenges of their application. However, the implementation of MPs is challenging in all circumstances. These principles call for an ambitious agenda that has often been difficult to implement (Msomphora et al., 2022).

At the Nicaragua level, the Ecosystem Approach has been implemented through compliance with the Convention on Biological Diversity-CBD (MARENA, 2015). Forest management has also been implementing the Ecosystem Approach in legislative aspects (Campos et al.,2007). However, there is no knowledge about how the principles of the Ecosystem Approach could be applied in farm management.

In this context, this article shows the results of a study carried out on 455 farms located in the north-central part of Nicaragua, in an area dominated by small farms, where self-sufficiency agriculture predominates. Thus, the objective of this work is to know if the LUMIs implemented in small farms in the study area have followed the Ecosystem Approach in line with promoting sustainable development. Such analysis should reveal the weaknesses and strengths of land management practices carried out to date.

Specifically, the objectives of the work have been:

- Extract from each LUMI the indicators on its compliance and select those related to the EA.
- Classify the 455 farms analysed according to their involvement in the adoption of land management measures based on the EA.
- Evaluate differences on resource sources, soil conservation practices, and gender and educational level involved in farm management.

2. Methods

2.1. Study area

Nicaragua's small farm agriculture is characterized by the production of food for family consumption. Surplus products are marketed to generate economic income that contributes to satisfying basic household needs. Farmers have links with cooperatives and with the state or private sector who provide them with technical assistance services, access to financing, training and marketing of products. Farmers who do not have these links carry out their own farm management. Good management of the soil resource is essential for the existence of small farm agriculture.

Small farms are managed at the family level. They have minimal technologies, productive infrastructure, inputs, equipment and tools or perhaps in quantities that are not sufficient for the operation of the productive system. The soil on these farms is used for planting basic grains, orchards, fruits, roots, tubers, and raising small livestock (yard birds and pigs). Large livestock farming consists of a few animal units per farm (cattle and horses). These farms have also cocoa or coffee agroforestry systems, which can reach areas of less than 1ha. Good soil management practices on these farms are associated with the establishment of living barriers, crop rotation, agroforestry systems, the use of organic fertilizers, control of pests and diseases in crops through biological products or comprehensive management practices.

The study was carried out on 455 farms located in three Territorial Development Areas (TDAs) in central Nicaragua. A TDA is a territory representative of the socio-economic and environmental conditions of a municipality and is delimited by a leading local agent, with a multistakeholder approach and a territorial rural development rationale.

The Organization for Economic and Social Development for Urban and Rural Areas (ODESAR), the Women and Community Economic Development Foundation (FUMDEC) and the Mother Earth Foundation (FUMAT) manage the TDAs of El Tuma-La Dalia, El Cuá and Waslala, respectively, with the technical and financial cooperation of the Aid in Action Foundation (AeA). These organizations have designed and implemented long-term interventions in the study area to improve the living conditions of the farmers.

The three selected TDAs are located in the municipalities of El Tuma-La Dalia (Matagalpa Department), El Cuá (Jinotega Department), both in the central region, and Waslala (RACCN Department), located in the northern Caribbean region. The three municipalities belong to the Caribbean slope of Nicaragua. These municipalities are part of the Peñas Blancas biological corridor and the buffer zone of the BOSAWAS Biosphere Reserve, which in turn connect with the Mesoamerican biological corridor (Fig. 1).

The climate of the study area is tropical sub-humid with annual rainfall between 1800 and 3270 mm and average annual temperatures between 22 and 26.5 °C. Land use is predominantly dedicated to agroforestry systems of coffee and cocoa, basic grains, livestock and, to a lesser extent, roots and tubers, orchards, fruit and musaceous crops, which in turn form the basis of the farmers' income and food security in the area.

2.2. Methodology

The methodology of this study was designed following a theoretical review of the Sustainable Development Goals (SDGs), Ecosystem Management (EM) and Land Use Management Initiatives (LUMI) carried out in the study area. Based on this information, representative indicators were compiled, which made it possible to design a survey aimed at gathering information on the strengths and weaknesses of land use management carried out by farmers in the study area (Fig. 2).

A description of the 2030 agenda and its goals (SDGs) was provided, mainly Goal 15, which focuses on the importance of sustainable management of terrestrial ecosystems, including land resource management. Subsequently, the conceptual basis of EM and its principles were documented in order to highlight the relevant role of the sustainable use of land and its ecosystem services for human well-being. Finally, theoretical information was gathered on which Land Use Management Initiatives (hereafter referred to as LUMI) have been implemented in the study area and which apply the principles of ecosystem management. The following eight initiatives were found to have been implemented:

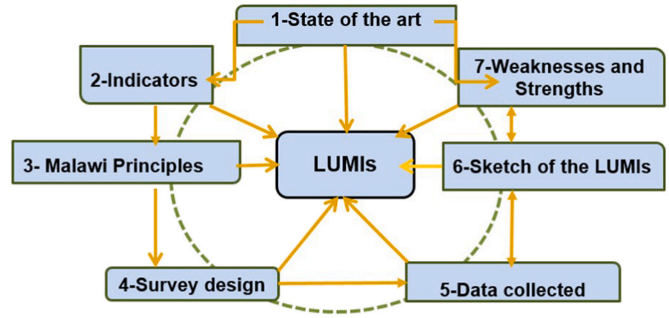

Fig. 2. Diagram of the methodology used to typify land use management initiatives in the study area.

- Nicaragua Biodiversity Plan
- Landscape study
- Territorial Rural Development
- Agro-ecological initiatives
- Integrated River Basin Management (IRBM)
- Integrated Water Resources Management (IWRM)
- Initiatives implementing agroforestry
- Integrated Disaster Risk Management (IDRM)

Information was collected on how these initiatives have been implemented in the study area in order to see if there were significant measurable differences between each, to identify their strengths and

Fig. 1. Location of the study area. W: Waslala, C: El Cuà, D: El Tuma-La Dalia.

weaknesses and their consistency with the principles of EM (Malawi Principles-Supplementary Data 1). Their indicators were documented and described in strategies at the regional (Central America) and national level, as well as in plans, programmes, and projects in the study area. The indicators enable the measuring of the results obtained by each of the initiatives in the study area.

A total of 186 indicators were collected and organized into the following dimensions: agriculture, household economy, environment and production, community infrastructure and social fabric, using an Excel data matrix (Supplementary Data 2). A checklist was then applied to these indicators against the 12 principles of ecosystem management (CBD, 1998), the Malawi Principles, for consistency with these principles.

The indicators that showed consistency were selected for the design of a survey in order to collect information on the practices adopted by farmers in the study area. In total 25 indicators (Supplementary Data 3) were selected according to the following selection criteria:

- ❖ The content of the indicator fit in one of the proposed dimensions: agriculture, family economy, environment and production, community infrastructure or social fabric.
- ❖ The indicator had frequency with comparative advantages within the initiatives and adhered to the principles of ecosystem management.
- ❖ It was approved by local stakeholders in the study area.
- ❖ The meaning of the indicator was intelligible to farmers

2.3. Survey design and dissemination

An initial version of the survey was designed based on the 25 selected indicators. The survey was then presented to leading local actors. Based on the feedback received, the survey was revised and a second version was designed. Finally, this version was reviewed by a panel of experts in order to obtain the final version. This version was implemented in digital format using the Survey 123 application of ArcGIS Online. The survey was structured in seven blocks of questions that enabled the collection of: i) Respondent information, ii) Location of the farm, iii) Life in the community, iv) Farm characteristics, v) Production and land use, vi) Land management on the farm, vii) Proposed land use on the farm (Supplementary Data 2).

A sample of 455 farmers out of a total population of 823 farmers in the study area (55.3%) participated in the survey. The responses were distributed among the municipalities of El Tuma-La Dalia (140; 30.8%), El Cuá (122; 26.8%) and Waslala (193; 42.40%). Simple random sampling was used to select the sample, based on farmers' databases provided by the leading local actors managing land use in the study area.

The survey response process was carried out through direct farm visits and farmer meetings, with the participation of community promoters and leading local actors. The information was recorded digitally using mobile phones and then uploaded to the Survey 123 platform of ArcGis Online. Prior to completion of the survey, technical training was provided to selected organizers in order to homogenize understanding of the terms used in the survey and how the questions should be explained to the farmers, the recording of information and defining logical methods for the response collection process.

2.4. Interviews with local actors

Based on the farmers' survey, the following blocks of questions were selected: production and land use; land management on the farm; and proposed land use on the farm, in order to interview the institutional decision-makers in land use management. Twenty-seven institutional representatives from El Tuma-La Dalia (8), El Cuá (8), Waslala (11), including cooperatives, NGOs and the national production system (State) participated. Interviews were conducted through direct visits to representatives of institutions and through multi-stakeholder sessions (institutional coordination) that were already established for the management of the territory. The actors' responses were used in a complementary way to describe land use management on the farms.

2.5. Data processing

The data for this study come from three sources of information. Initially, 186 indicators used in the design of the LUMI were collected. Subsequently, 455 farm surveys were obtained. In parallel, public-private institutions were interviewed (27). These data were analysed using descriptive statistics and multivariate techniques with IBM SPSS Statistics 27.0 software.

Three multivariate techniques were combined for the analysis of the results obtained in the surveys: a Principal Component Analysis (PCA) was carried out on the quantitative variables in order to select the most explanatory aspects. The two variables, valuation of the LUMI and participation of young people and women in the TDA, were standardized in order to homogenize their variances. The 455 farms were then classified by hierarchical clustering, using Ward's method and the Euclidean squared distance to classify the LUMI at farm level. Finally, a Multiple Correspondence Analysis was carried out in order to describe the association of qualitative variables according to the cluster.

3. Results

3.1. Indicators extracted from the land use management initiatives – LUMI

As mentioned in the introduction, the literature review showed that there are 8 LUMI being implemented in the study area (Table 1). These LUMI relate to projects, plans and strategies that have been implemented over time.

From the content review of the LUMI, 186 indicators were obtained. These were organized into 6 dimensions (Supplementary Data 1) according to indicator content for ease of analysis. Fig. 3 shows that indicators on the environment and social fabric are the most common.

Furthermore, Table 1 shows that the LUMIs in agroforestry (AGF), territorial rural development (TRD) and integrated river basin management (IRBM) have the highest number of indicators.

3.2. LUMI and Malawi principles (MP)

The indicators extracted from each LUMI were analysed in order to see if they were related to any of the ecosystem management principles or Malawi Principles (CBD, 1998).

The result of the analysis is shown in Fig. 3. It can be seen how the LUMI in the study area include from one to five Malawi Principles (MP) at most (Supplementary Data 1). The agroforestry LUMI has the highest number of indicators (44) related to ecosystem management principles, while the landscape conservation initiative has only 8 indicators measuring whether the management type is aligned with the Malawi Principles (MP).

Fig. 3 shows that the indicators of each LUMI are aligned with the

Table 1
Number of indicators extracted from each of the Land Use Management Initiatives (LUMI) implemented in the study area.

Land Use Management Initiatives (LUMI)	no. of indicators extracted
Agroecology (AGE)	12
Agroforestry (AGF)	44
Biodiversity (BIO)	26
Territorial Rural Development (TRD)	31
Integrated River Basin Management (IRBM)	30
Integrated Risk and Disaster Management (IRDM)	12
Integrated Water Resources Management (IWRM)	23
Landscape conservation (LC)	8
Total	186

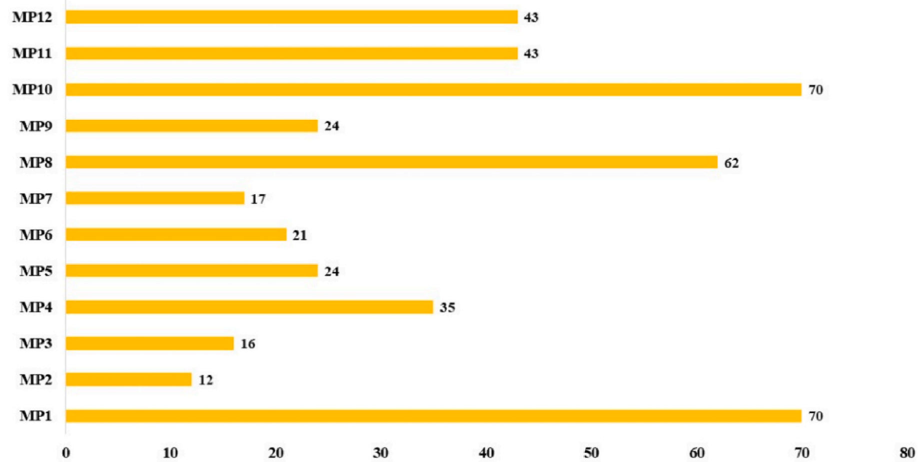

Fig. 3. Comparative representation of the most applied MPs in the LUMI of the study area.

Malawi Principles. The agroforestry LUMI stands out with a total of 93 links between its indicators and the principles of ecosystem management. On the other hand, the landscape conservation LUMI only shows 8 links with the MPs (Supplementary Data 1).

The principles on social participation (MP1), the balance between conservation and use of biodiversity (MP10) and long-term management (MP8) are the most frequent MPs (Fig. 3). The least frequent MPs are appropriate scale (MP7), consideration of effects within and outside the ecosystem (MP3) and decentralization (MP2).

3.3. Typification of farms in the study area in relation to the application of land use management initiatives (LUMI)

3.3.1. Variable and cluster selection

Prior to the cluster design, a Principal Component Analysis (PCA) was performed on the quantitative variables. These include i) valuation of the application of the LUMI, ii) participation of women and young people in land use decision making, iii) besides of farm area, total agroforestry area (AFA), and cocoa AFA and coffee AFA, were considered (Figs. 4 and 5).

Qualitative variables include 'participation in LUMI' and 'gender of farmers'. These data were explained using a Multiple Correspondence Analysis (MCA) (Table 2). These techniques are commonly used; for example, López-Roldán and Fachelli (2015) explained the criteria for using them. These indicators were useful for following the progress of each LUMI on the farms analysed. They determined whether farmers were involved in each management initiative and whether they applied the learnings from the LUMI on their farms. This allowed us to identify measurable differences for the classification of farms according to their participation in each LUMI.

The results of the Multiple Correspondence Analysis (MCA) of the indicator 'farmers' participation in the LUMI' demonstrate 72.10% of the variability of participation associated with community water management (IWRM), territorial rural development (TRD), landscapes (LC) and river basin management (IRBM) (see Table 2). The rest of LUMIs demonstrate a variability of less than 70% (minimum criterion in the MCA) and are therefore not determinant.

Table 2 shows that the river basin management LUMI has a slightly higher discriminant measure than landscapes (71.8%). In the second dimension it can be seen that the variable 'farmer participation in LUMI Integrated Water Resources Management' (IWRM) has a higher discriminant measure (77%). Territorial Rural Development (TRD) forms an intermediate category that is clearly demonstrated in the first and second dimension (70%).

The gender of the farmers was used as a supplementary variable to complement the interpretation of the factors of the active variable (participation). It is commonly used in the study area to show women's participation in farm management. The gender variable (female/male)

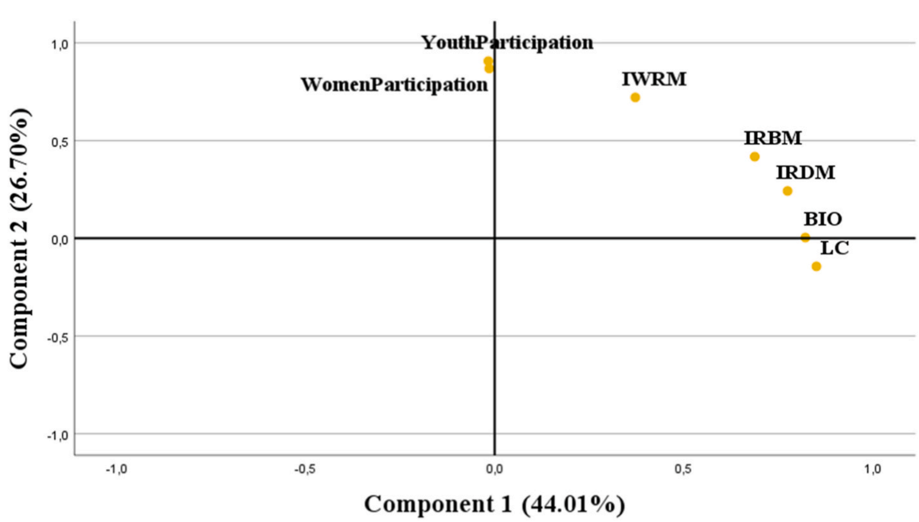

Fig. 4. Components in rotated space of the variables: 'valuation of the LUMI' (scale of 1–10; 1 = worst, 10 = best); valuation of the participation of women and young people in decision-making (scale of 1–10; 1 = worst, 10 = best), at the farm level in the study area.

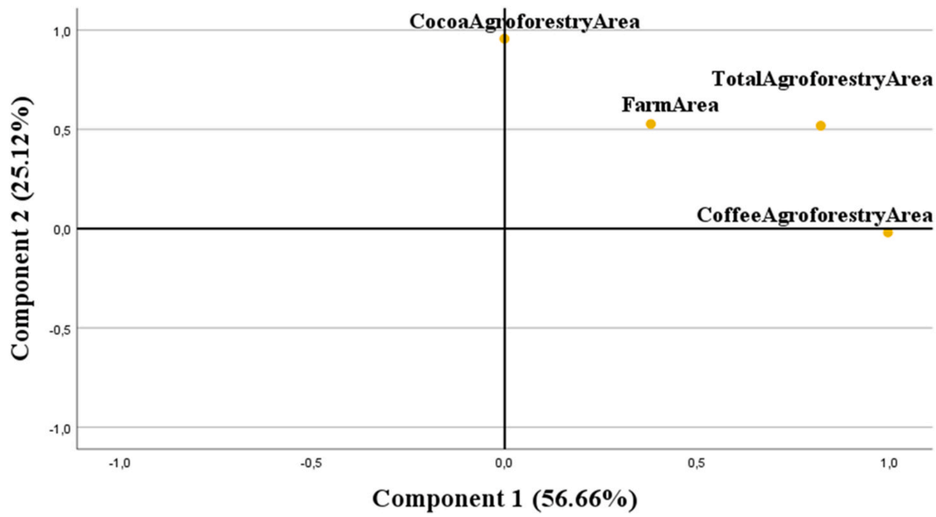

Fig. 5. Main components in rotated space of the variables farm area and farms agroforestry systems in the study area.

Table 2
Multiple Correspondence Analysis (MCA) discriminant measures for the variable: 'farmers participation in LUMI'.

Participation	Dimension1	Dimension2	Average
IRBM	0.549	0.169	0.359
IWRM	0.223	0.547	0.385
TRD	0.373	0.323	0.348
LC	0.516	0.183	0.349
% variance	41.513	30.555	36.034

IRBM: river basin management; IWRM: community water management; TRD: territorial rural development; LC: landscapes.

was linked with participation.

The PCA obtains two components that demonstrate 70.7% of the variance with regard to the indicators 'assessment of the application of the different LUMI in the farms', 'participation of women' and 'participation of young people' in decision-making (Fig. 4). The analysis shows that the highest rated LUMI are Integrated Risk and Disaster Management (IRDM), Biodiversity conservation (BIO), Landscape Conservation (LC) and Integrated Water Resources Management (IWRM). Additionally, the participation of women and young people in decision-making on the farm is rated highly.

On the other hand, Fig. 5 shows the PCA for the variables 'area of the farm' and 'area occupied by coffee or cocoa agroforestry systems'. The two components account for 81.78% of the variance.

The most revealing variables in the PCA and MCA were used to classify farms using the hierarchical clustering technique, with Ward's method and Euclidean squared distance. Vilà-Baños et al. (2014), López-Roldán and Fachelli (2015) explained a sequence of steps in order to apply this multivariate technique. The results of the analysis allowed us to obtain three clusters composed of five farm typologies, which are visualized in the dendrogram in Fig. 6. These typologies were defined a priori and subsequently checked by means of a sedimentation graph in PCA (scree test technique).

The clusters are made up of the following groups: i) Farms under Ecosystemic Land Use Management - Active (FELUM-A), which includes Typology 1 (FT1) farms. ii) Farms under Ecosystemic Land Use Management - Improvable (FELUM-I), which classifies farms of Typology 2 (FT2) and Typology 3 (FT3), iii) Farms under Ecosystemic Land Use Management - Moderate (FELUM - M), which includes farms of Typology 4 (FT4) and Typology 5 (FT5).

Based on their similar characteristics, FT1, FT2, FT3 and FT5 are small farms ranging in size from 3 to 6 ha (Table 3). FT4 is the only typology with medium-sized farms with an average area of 40 ha. The farms as a whole have agroforestry systems that, depending on the agroecological conditions, can be coffee or cocoa. Coffee systems are predominant in the municipalities of El Tuma-La Dalia and El Cuá. On the other hand, cocoa systems are more prevalent in the municipality of Waslala.

Regarding the average age of the manager of each farm, in FT2, FT3 and FT5 the average age was similar, 39 years, while FT1 and FT4 had an average age of 47 years. FT2, FT3 and FT5 include 50% women while in FT1 and FT5, 51.29% and 54.16% are women, respectively. This result in the gender variable shows that the farm sampling used in this study took gender equality into account (Table 3).

With regard to the characteristics that differentiate each cluster (Table 3), it can be observed the following aspects:

a) Farms under Ecosystemic Land Use Management - Active (LUMI-A).

FT1 farms were classified in this cluster. It is composed of 154 small farms (3.82 ha) and an agroforestry land use of 0.89 ha with a predominance of the coffee system (0.67 ha). In FT1, Integrated Water Resources Management (IWRM) reached the highest values of participation and valuation (86.36% and 6.12 respectively). All farms in this group are characterized by the highest values for the participation of women and young people in land-use decision-making (9.10 and 8.79 each). Therefore, it is the group that stands out the most in incorporating gender and generational change.

b) Farms under Ecosystemic Land Use Management - Improvable (LUMI-I)

This cluster includes two types of farms:

Typology 2 (FT2): 127 small farms were classified in this group (6.37ha) with an agroforestry land use of 1.27 ha and a greater presence of the cocoa system (0.86ha).

Farmers belonging to this typology values very well their participation in the initiatives of Agroforestry systems (AGF) and the Integrated River Basin Management (IRBM) in order to manage the land resources on the farms (35.43% participation). But this typology has the lowest values in relation to the participation of women and young people (3.57 and 1.72 respectively).

Typology 3 (FT3) is composed of 108 small farms (5.03ha) with an agroforestry land use of 0.61 ha. In these farms the areas of the agroforestry system established for coffee (0.28) and cocoa (0.33) are similar. The LUMI with the highest participation and valuation are associated with the integrated management of river basins (IRBM) and biodiversity (BIO), with values of 69.44% and 3.49 respectively. Low values are obtained with regard to the participation of women and young people (4.59% and 3.36% respectively).

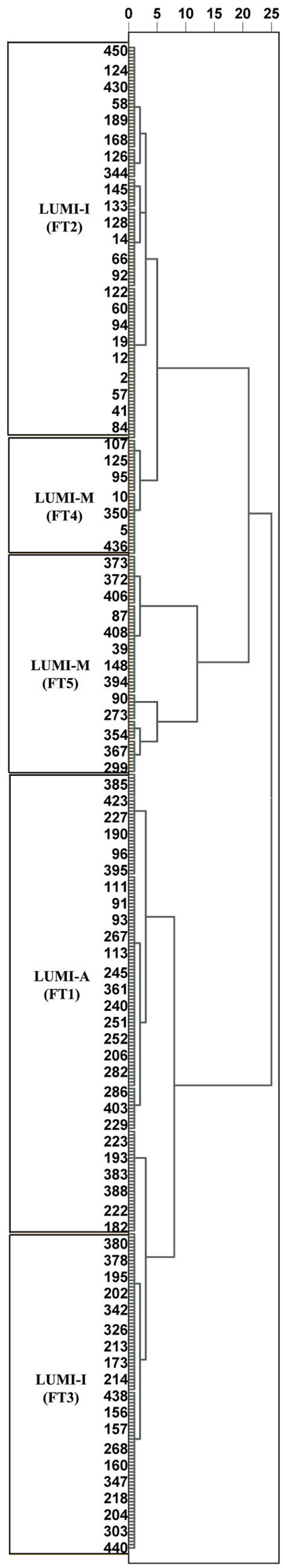

Fig. 6. Cluster showing the classification of farms according to the following variables: valuation and participation of farmers in the various LUMI; gender of the person managing the farm; area of the farm and area under agroforestry systems (Numbers in the cluster indicate the farm codes).

Table 3
Variables that explain the classification of farms: age; surface; gender and youth incorporation in decision-making (average) and best valued LUMIs regarding farmer's participation (number of participants) and usefulness (average).

Variables	LUMI-A	LUMI-I		LUMI-M	
	FT1	FT2	FT3	FT4	FT5
Number of farms	154	127	108	24	42
Average age of the farmer	47	39	39	47	39
Farm area (ha)	3.82	6.37	5.03	40.46	3.26
Agroforestry systems area (ha)	0.89	1.27	0.61	5.01	0.45
Coffe agroforestry system area (ha)	0.67	0.41	0.28	4.08	0.33
Cocoa agroforestry system area (ha)	0.22	0.86	0.33	0.92	0.11
% of women who provided farm data	51.29	49.60	46.29	54.16	50
% of men who provided farm data	48.71	50.40	53.71	45.84	50
Participation of women in decision-making on farms	9.10	3.57	4.59	6.54	7.07
Youth participation in farm decision-making	8.79	1.72	3.36	6.42	5.43
Participation in DRT	22	32	68	18	25
Participation in IWRM	**133**	35	58	15	24
Participation in IRBM	94	45	75	16	29
Rating (IRDM)	2.08	0.15	2.86	4.88	7.29
Rating (BIO)	1.38	0.54	3.49	4.00	7.07
Rating (LC)	0.10	0.50	3.12	4.79	7.76
Rating (IWRM)	**6.12**	1.09	2.39	4.96	6.76

c) Farms under Ecosystemic Land Use Management - Moderate (LUMI - M).

This group of farms is classified into two typologies:

Typology 4 (FT4) is the smallest of the groups and is made up of 24 medium-sized farms (40.46 ha). These farms have an average land use of 5 ha agroforestry systems and the most prevalent is the coffee agroforestry system with an average of 4ha. The participation value for land use management initiatives is obtained by Territorial Rural Development (75%). The average value in terms of the participation of women and young people in land use decision-making is 6.5.

Typology 5 (FT5) is made up of 42 farms that are characterized by being the smallest (3.26ha). Land use with agroforestry systems reaches an average of 0.5ha with a predominance of the coffee agroforestry system. Soil management practices on these farms take into account actions that benefit the landscape (LC initiative) with a good valuation of that initiative (7.76). The results indicate that the participation of women and youth in farm management decision-making is well valued with scores of 7.07 and 5.43 respectively.

3.4. Qualitative data associated with farm clusters

With regard to qualitative data, the following aspects were taken into account: family education level, farm management, main sources of income and soil conservation practices. These aspects were considered to be relevant because they could show land management on the farms related to the level of education and sources of income. These data were analysed using a Multiple Correspondence Analysis (MCA).

Table 4 shows that farm cluster, education level and farm management are associated. FELUM-A and FELUM-I clusters are associated with a primary (FT1 and FT2) and secondary (FT3) level of education. The farms with no education level are more linked to FELUM-A (FT1). The FELUM-M cluster is more related to secondary education (FT4) and university education (FT5). Technical education has little association with the farm clusters. Primary and secondary education, 78% of the total number of farms, are the predominant educational levels.

Table 4 shows that farm clusters, income sources and soil conservation practices are linked. As far as farm management is concerned, the categories both (male and female participants) and only male are the most prevalent and are associated with all three clusters. Farms

Table 4
Multiple Correspondence Analysis (MCA) discriminant measures for the farm clusters linked to: farm management and education level; income sources and soil conservation practices.

Variables	Dimension1	Dimension2	Average
Clusters	0.483	0.346	0.415
Farm management	0.292	0.493	0.392
Educational level	0.546	0.431	0.488
% variance	44.032	42.338	43.185
Clusters	0.644	0.541	0.593
Sources of income	0.583	0.324	0.454
Soil conservation practices	0.425	0.490	0.457
% variance	55.081	45.156	50.119

managed by women form is not associated with the clusters. Disaggregating only farms managed by women and men shows that only 25% of the farms are managed by women. Cluster FELUM-A has the highest percentage of farms managed by women (36%). The lowest percentage of farms managed by women is 19% and corresponds to the cluster FELUM-I.

The farm is the main source of economic means in the farm typologies. In the LUMI-A cluster wages and remittances are complementary sources of family income. The LUMI-I cluster combines in its sources of income the local marketing of various products and the sale of labour outside the farm. On the other hand, LUMI-M is the cluster associated with entrepreneurship.

Almost all farms of the three clusters establishes practices to prevent soil erosion and improve nutrient recycling through the establishment of living barriers and crop rotation. Besides some farms of the FELUM-I cluster use organic fertilisers and the application of biological products to control pests and crop diseases.

4. Discussion

4.1. Integration of the ecosystem approach in the LUMIs

The results of the literature review carried out show that up to 8 LUMIs have been implemented in soil management on small farms in Nicaragua between 1994 and 2022. In their beginnings (1950–1990) these LUMIs worked through sectoral approaches and based on Rio Summit (1992) began to gain more strength as comprehensive programs. However, there are no known previous studies that reflect to what extent these initiatives have applied the ecosystem approach in Nicaragua. This is because this approach has had limited application, even at the Latin American level (Andrade et al., 2011).

It is known that the ecosystem approach is a strategy for the integrated management and sustainable use of land (CBD, 2000). However, in Nicaragua its applicability involves knowing the weaknesses, strengths and areas for improvement presented by the LUMIs that have included this approach in the management of small farms in Nicaragua. The problem of applying the ecosystem approach is linked to the fact that it is an ambitious agenda and sometimes difficult to implement (Msomphora et al., 2022). For example, Waylen et al. (2013), points out that a good application of this approach involves maintaining its *ethos*, being implemented and evaluated.

Regarding the LUMI indicators, the results reveal that the LUMIs studied present 186 indicators linked to measuring the improvement of the environmental situation, agriculture, community infrastructure, social fabric and family income of small farms in Nicaragua. The strengths of the LUMI lie in environmental conservation and social fabric goals. While the Indicators that relate to economic income and productivity are less frequent and therefore are areas of fundamental improvements to consider in the application of LUMIs.

Regarding the environmental strengths, they are due to the fact that the area selected for this study is located in the Peñas Blancas protected area and the BOSAWAS Biosphere Reserve. In these areas, one of the goals at the country level revolves around protecting natural resources and promoting the inclusion of the population (MARENA, 2020a). On the other hand, the improvement of the social fabric is associated with the fact that small farms have been taken into account for the design of the LUMIs.

Referring to areas of improvement, although income and productivity indicators are less frequent, it does not mean that LUMIs should promote them and stop promoting environmental and social indicators. However, in the design of LUMIs it is important to take into account that good productivity can lead to an increase in economic income and it is interrelated with good soil fertility. On the other hand, low productivity in many tropical agricultural systems is interrelated with the loss of soil fertility due to erosion and decrease in economic income (Millennium Ecosystem Assessment, 2005; Sistla et al., 2016; PDT, 2014; Sepúlveda et al., 2020).

In these circumstances, the design of LUMIs should be linked to indicators that improve productivity and family economic income. This is because in the management of small farms in Nicaragua, the economic benefit that farmers can receive through increased production is vital to satisfy basic family needs. Otherwise, if productive aspects and income were not taken into account in the design of LUMIs, the ecosystem approach would probably not be well adopted in the management of small farms. Tatis-Diaz, et al. (2022) have already pointed out that agricultural income constitutes a determining socioeconomic factor in the adoption of sustainable practices in the management of small farms.

Regarding the inclusion of the Malawi Principles (MPs) in the LUMIs, the findings of this study have shown that the LUMI includes all 12 MPs. However, they have more frequently integrated between one and five MPs. These results are similar to the findings of García Azuero et al. (2005), in the study of four Natural Resource Management initiatives in Costa Rica that analyzes MPs based on common elements existing among the selected initiatives. They are in line with the findings of Wilkie et al. (2003) who compare forest management and the ecosystem approach in an international context. They agree with the results of Ianni and Geneletti (2010), who applied MPs to identify forest restoration priorities in South America. They coincide with the findings of Smith and Maltby (2003), who analysed the ecosystem approach in 26 case studies from South America, South Africa and Southeast Asia. These similarities in the application of MPs are associated with common objectives that these initiatives have pursued, such as: the participation of the population, the management of natural resources and the involvement of the agents involved in management.

In this study, MP10 is one of the most frequent principles included in LUMIs. While in the results of García Azuero et al. (2005) as well as Alam and Mohammad (2018) obtained inverse results in MP10. In the first case this is because MP10 is a principle more associated with practices of sustainable use of biodiversity and on the other hand it has to do with the number of possible binding observations. In the study carried out in Costa Rica, the analysis is carried out based on relevant elements of the initiatives from a theoretical perspective and MP10 only has 1 element. While, in the present study, indicators of practical application are taken into account and MP10 reaches 70 links. In the second case, it is due to the fact that the study carried out in Bangladesh carries out a more evaluative analysis of MP10 and shows that a balance has not been achieved between conservation and sustainable use of biodiversity. Instead, in this study the objective is to know if the MP10 has been incorporated into the LUMIs, but the status of the use and conservation of biodiversity is not addressed.

Smith and Maltby (2003) reported that community participation and capacity building are relevant in MP2. They link the decentralization of management (MP2) with the involvement of stakeholders (MP12) and the use of local knowledge (MP11). While these same elements, in this study are associated with MP1, MP11 and MP12. This is due to the interrelation that exists in the MPs and the dynamics of management in each country. For example, in Nicaragua the participation of the population (MP1) implies that the largest possible number of stakeholders

(MP12) are involved in the management of knowledge and land resources (MP11); which would lead to stakeholders being in better capacities to manage the soil resource (MP2).

Phillips and João (2017) found that the ecosystem approach has been considered in case studies related to land planning in the United Kingdom. On the other hand, they refer to the fact that the ecosystem approach provides an important opportunity to include MPs due to its strategic and integrated nature, although they highlight the need for better management of MP10 (Biodiversity Conservation). Similarly in our study, the ecosystem approach has been taken into account in the LUMIs. However, in Nicaragua the inclusion of this approach in the LUMIs has had more strength in environmental and social aspects. Therefore, it can be considered an opportunity for better soil management, as long as MP4 and MP10 are enhanced.

The findings of this study showed that MP3 is one of the least frequent principles in LUMIs. This may be due to the need to generate more information and strengthen capacities that allow managing the repercussions involved in the use of ecosystem services. García Azuero et al. (2005), consider that MP3 is a transversal aspect to the other principles and suggest putting greater emphasis on it in the designed initiatives. Instead, Waylen et al. (2013) found that MP3 is the least likely principle to be considered in 24 case studies of applying the ecosystem approach in the United Kingdom. The elements that explain its results are associated with the need to understand ecological interactions and improve the management of organizational-administrative limits associated with biophysical ones.

4.2. *Typification of the farms in the study area according to land use management initiatives (LUMI)*

The farms in the study area are classified into three clusters: farms under active ecosystem management (LUMI-A), moderate (LUMI-M) and improvable (LUMI-I). The active ecosystem management farm typology (FT1) is linked to the community water management initiative (IWRM) and has the highest values for participation, valuation, inclusion of women and young people. In contrast, moderately managed farms (FT4 and FT5) have intermediate values and they are associated with the territorial rural development (TRD) and landscape initiatives (LC). The lowest scores corresponded to the farms with improvable management (FT2 and FT3) and are related to river basin management (IRBM) and agroforestry (AGF) initiatives.

The biodiversity (BIO) and disaster risk management (IDRM) LUMI did not influence the ranking of farms because they depend on institutional management and not only on farm management. Similarly, agroecology (AGE) has no influence, because it is applied more as agroecological practices on farms than at the LUMI level.

The results regarding the number of farm typologies are within the range of typologies established in previous works (Betancourt et al., 2005; Ravera et al., 2014; Haggar et al., 2015; Fréguin-Gresh et al., 2017; Pinoargote et al., 2017; Lan et al., 2018; Richards et al., 2021; Notaro et al., 2022). However, the results differ in the classification objective of the farms. Moreover, the farms in the study area are small (95%) and medium-sized (5%), (Table 3). Similar to the findings of Haggar et al. (2015) and Richards et al. (2021).

Our findings showed that small farms are associated with the conservation of a greater number of soil ecosystem functions. This is in line with (Ren et al., 2019), who point out that the size of the farms plays a determining role in sustainable agriculture. It agrees that farm size and management influence land use and soil conservation decisions (Faustino and Jiménez, 2000; IICA and IFAD, 2021). It is known that the productivity of agri-food systems is a function of good soil fertility. Sustainable land use is essential to sustain national food security. This work is in the hands of small farmers (PNLCP, 2022). Under these circumstances, the results of this study allow us to argue that the ecosystem approach is an option for sustainable soil management on small farms in Nicaragua.

Regarding the educational level, the smallholders of the study area have followed studies corresponding to the primary and secondary levels, similar to the findings of Fréguin-Gresh et al. (2017) and Lan et al. (2018). Additionally, field schools (Mercado et al., 2017), technical and university training (INATEC, UNICAM/UNAN-Managua) and cooperation projects (AeA-Nicaragua) have been implemented in order to strengthen farmers' capacities. From the perspective of the ecosystem approach, this result is linked to MP1, MP11 and MP12. However, in the management of small farms there is a need to integrate these capabilities. It is therefore essential to merge and leverage these existing local capacities based on farm-level practices for soil restoration and conservation.

Regarding the farm management, it can be observed that the clusters are mostly associated with the categories of both (men and women) and only men. In the 'both' category, the proportional weights of men and women are not differentiated. Therefore, if we look separately at the farms managed by men and women (230), we find that only 25% of these farms are managed by women. This result is similar to the gender gap (24%) reported by FAO (2023a,b) in a general study of agri-food systems. From the ecosystem perspective, this would imply making improvements in MP1 and MP11.

In the study area, cross-sectional gender equity strategies are implemented in programmes and projects associated with soil resource management. These have had effective results (Mercado et al., 2017; FISE, 2021). However, equitable participation must be continuously improved in order to strengthen soil resource management from an ecosystemic perspective (FAO, 1999; Altieri, 2002; Ezeaku and Davidson, 2008; Sardá et al., 2013; Brody, 2003; Oliveira and Meyfroidt, 2021). In line with (Snapp et al., 2018; Mponela et al., 2023; Mathys et al., 2023), women's participation is essential for sustainable land use and gender equity indicators must be designed focused on productivity and the decision-making process in households (Gutierrez-Montes et al., 2020).

The main source of household income is the farm, with wages and remittances being less frequent. These results at the farm level are consistent with the need to design initiatives that integrate productivity indicators. The LUMI-I and LUMI-M clusters show experiences of marketing farm products and community enterprises that can enhance the family economy of farmers in the study area. In the context of applying the ecosystem approach, this finding confirms that there is a need to enhance MP4 and MP10 (economic income and productivity on small farms). This study does not address the elements that must be managed to increase income and productivity. However, they are relevant aspects to consider in the design of new initiatives that plan to incorporate the ecosystem approach with small farmers.

When it comes to soil management practices, our results reveal that soil conservation and restoration in farm typologies is linked to practices that contribute to preventing degradation, recycling nutrients and preserving soil health and biodiversity. In the ecosystem perspective, this result is mainly linked to MP10; However, it is transversal in the restoration of ecosystems. In line with (FAO, 2015), these findings are key for the design of indicators associated with sustainable soil and ecosystem management.

5. Conclusions

Our findings show that Land Use Management Initiatives (LUMIs) in Nicaragua use the ecosystem approach to support sustainable development on small farms. These initiatives typically include one to five Malawi Principles (MP). We found that the most common principles in the (LUMIs) were: Integrated natural resource management (MP10), social participation (MP1), and long-term objectives (MP8). However, considering appropriate scales (MP7) and the effects inside and outside the ecosystem (MP3) were less commonly applied. Overall, the LUMIs in the area showed strengths in building social connections and achieving environmental goals.

The results also reveal that soil resource management on small farms is classified in three clusters of farms: Active, Moderate and Improvable. The highest, medium and lowest values for participation, gender inclusion and valuation of land management initiatives corresponded to active, moderate and improvable management, respectively. Cluster LUMI-A was linked to community water management. The LUMI-M cluster was associated with territorial rural development and landscapes conservation and the LUMI-I cluster was related to river basin management and agroforestry initiatives.

Regarding the educational level; primary and secondary education levels were the most predominant in the farm clusters. In terms of management, the farms were mainly managed by men. Only 25% of these farms were managed by women, which coincides with the 24% gender gap reported by FAO (2023a,b) in agri-food systems. In the study area, the main source of income is the farm. However, in the LUMI-I and LUMI-M clusters, there was evidence of experiences of commercialization of farm products and community enterprises. In terms of soil conservation practices, the LUMI-A and LUMI-I clusters were linked to preventing degradation, recycling nutrients and conserving biodiversity. In contrast, LUMI-M was more associated with preventing soil degradation. These results highlight the need to include on improving productivity, household income and gender equity in the LUMIs design.

This study suggests that future initiatives aiming for sustainable soil management on small farms in Nicaragua can benefit from incorporating the ecosystem approach. However, for successful adoption, it's crucial to include indicators focused on improving economic aspects and productivity on small farms (Linked to: MP10, MP11, and MP12). It's important to recognize that small farmers, despite supporting the country's food security, may have limited resources to implement this approach on their farms.

CRediT authorship contribution statement

William Muñoz: Writing – original draft, Methodology, Investigation, Conceptualization. **Carla Garcia-Lozano:** Methodology, Formal analysis, Data curation. **Diego Varga:** Software, Formal analysis, Data curation. **Josep Pintó:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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