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Translated from the original in spanish

Original article

Bases for the redesign of coffee agroecosystems in the province Uige, Angola

Bases para el rediseño de agroecosistemas cafetaleros de la provincia Uige, Angola

Bases para o redesenho de Agroecossistemas cafeteiros de la província Uige, Angola

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ABSTRACT

The research is part of a doctoral thesis and had the objective of diagnosing agro-ecosystems dedicated to the production of *Coffea canephora*, in municipalities of the Uige province, Angola. For this purpose, a diagnosis was made, which took into account the establishment of agro-ecological indicators that allowed the characterization of farms, which were previously selected according to the socioeconomic conditions and coffee production results, in conjunction with specialists and community leaders. After being characterized and evaluated, the results showed, according to a Cluster analysis, the structuring of six groups of farms that have similarities in some cases and differences in most of the indicators evaluated. The indicators that most influenced the differentiation of these groups were: agricultural and industrial yields; topography; structural composition of shade; land use and tenure; soil agro-productivity; and traditional knowledge. Through them, the agro-ecological structure of the farms was defined, as a basis for making proposals for agro-ecological development, according to the potentialities found in each group.

Keywords: *Coffea canephora*; agroecological structure; sustainability; agroecology.

RESUMEN

La agroecología es una ciencia que se consolida como alternativa de conversión de los modelos de desarrollo agrícolas, basados en la utilización de altos insumos, hacia sistemas más diversificados que tienen en cuenta un manejo sostenible de los recursos naturales. La investigación tuvo como objetivo diagnosticar agroecosistemas dedicados a la producción de *Coffea canephora*, en municipios de la provincia Uige, Angola. Para ello, se realizó un diagnóstico que tuvo en cuenta el establecimiento de indicadores agroecológicos que permitieron caracterizar las fincas que previamente fueron seleccionadas atendiendo a las condiciones socioeconómicas y los resultados productivos de café, de conjunto con especialistas y líderes comunitarios. Luego de caracterizadas y evaluadas, los resultados evidenciaron, según un análisis de Clúster, la estructuración de seis grupos de fincas que poseen similitudes en algunos casos y diferencias en gran parte de los indicadores evaluados. Los indicadores que más incidieron en la diferenciación de estos grupos fueron los rendimientos agrícolas de despulpe e industrial, la topografía, la composición estructural de la sombra, el uso y tenencia de la tierra, la agroproductividad de los suelos y el conocimiento tradicional. A través de ellos, se definió la estructura agroecológica de las fincas, como base para realizar propuestas de desarrollo agroecológico, según las potencialidades encontradas en cada grupo.

Palabras clave: *Coffea canephora*; estructura agroecológica; sostenibilidad; agroecología.

RESUMO

A investigação forma parte duma Tese de Doutoramento e tive como objectivo: diagnosticar agroecossistemas dedicados à produção de *Coffea canephora*, en municípios da província Uige, Angola. Para isso, realizou se um diagnóstico, que tive da conta o estabelecimento de indicadores agroecológicos que permitiram caracterizar jácaras, que previamente foram seleçoadas atendendo às condições socioeconómicas e aos resultados produtivos de café, de conjunto com especialistas e líderes comunitários. Logo de caracterizadas e avaliadas, os resultados evidenciaram, segum uma análise de Clúster, a estruturação de seis equipes de fincas que possuem similitudes em alguns casos e diferenças em grande parte dos indicadores avaliados. Os indicadores que mais incidiram na diferenciação destas equipes foram: os rendimentos agrícolas de despolpe e industrial; a topografia; a composição estrutural da sombra; o uso y tenência da terra; a agroprodutividade dos solos; e o conhecimento tradicional. Através deles, definhou se a estructura agroecológica das jácaras, como baseamento para realizar propostas de desenvolvimento agroecológico, segum as potencialidades achadas em cada equipe.

Palabras clave: Coffea canephora, estrutura agroecológica, sustentabilidade, agroecologia.

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INTRODUCTION

Agroecology is a science that is consolidated as an alternative for the conversion of agricultural development models, based on the use of high inputs, towards more diversified systems that take into account a sustainable management of natural resources; this allows, to achieve a sustainable production and the restoration of agroecosystems (Toledo-Toledo, 2017; Contino *et al*., 2018).

In the last decade, the concept of Principal Agroecological Structure (PES) has emerged, related to the internal spatial configuration or arrangement, as a criterion of agroecosystemic connectivity (León, 2010); which was applied, for the first time, in a study of ecological farms dedicated to horticulture in Colombia (León *et al*., 2011).

This new concept allows the study and planning of the use of agro-ecosystems, through the characterization of the structural and functional relationships established by their components, in order to establish sustainable development strategies (León *et al*., 2014; Cleves *et al*., 2017).

Research carried out, as a descriptive or explanatory element of the phenomena that arise in agro-ecosystems, constitute experiences that demonstrate the potential of knowledge of the PA of a farm, for making decisions that improve its operation (González *et al*., 2018).

In Angola, coffee continues to be a crop of economic importance, being the main agricultural export product (MINAGRIF, 2017). This country, in the 70's, was the fourth largest coffee producer in the world, with *Coffea canephora* being the most represented, with 95%, before *Coffea arabica*, mainly in the Uige province (INCA, 2014).

However, in recent years the trend in the production of this crop is to decline, due to low productivity of agro-ecosystems, aging plantations and difficulties with technical assistance and lack of resources, which brings economic problems and lack of interest of producing families, for the care of their coffee plantations (INCA, 2019).

In view of the above, the government established a strategic plan to reactivate coffee production from 2013 to 2017, with programs aimed at increasing the area of cultivation, improving productivity and quality of the grain harvested. However, the proposals of alternative management of the coffee area, carried out in the province, find limitations in their implementation; fundamentally, for not having a real knowledge of the characteristics that present the agro-ecosystems that, at present, are dedicated to the production of this crop.

Based on this background, the research aimed to: diagnose agro-ecosystems dedicated to *C. canephora* production, as a basis for defining the farms with the greatest potential for agro-ecological development of coffee production.

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MATERIALS AND METHODS

For the study of the coffee agroecosystems, a general scheme was used, which had five fundamental stages, adjusted according to the proposed objective (Figure 1).

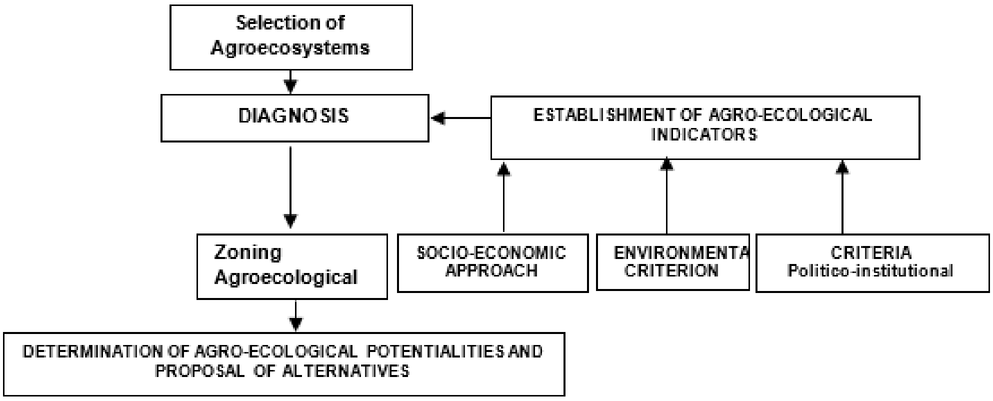

Figure 1. -Research scheme used in coffee agroecosystems in municipalities of the province Uige, Angola

Selection of Agroecosystems

The starting point of the study was the selection of the agro-ecosystems, which was done in conjunction with the INCA technician and the sample size was taken by the convenience method (Torres and Paz, 2008). To this end, the following were taken into account: socio-economic conditions and coffee production results.

Diagnosis

A characterization of the components and subsystems of production was carried out, as well as their functioning, dynamics and relations between them; for which indicators were established that allowed the characterization of the agro-ecological dimensions (Nicholls *et al.,* 2015). These were defined with the participation of producers, leaders and specialists in coffee production from the province and the INCA, through workshops. In addition, basic information was collected from 1554 selected coffee agro-ecosystems through formal and informal interviews and a pre-prepared and enriched questionnaire for this research, with contributions from local actors.

In the visits made to *C. canephora* farms, the number of individuals per tree species present in a hectare, identified with the support of the producers and the INCA's technician, was counted. With this result it was obtained a list of species of the flora by farm and locality; what allowed, to determine the specific biodiversity associated to the plantations of this culture, by means of, the proportional wealth and abundance of the present species.

In addition, the Shannon-Weaver (H') index was calculated (Shannon and Weaver, 1949), using the following formula (Equation 1).

$$H' = -\sum pi \ln pi \qquad (1)$$

Where:

pi - represented the proportional abundance of species *i*.

The interpretation of the index was assumed to be based on the criterion that values less than two (*<2*) suggest agro-ecosystems with relatively low species diversity and more than three (*<2*), with high diversity.

The information obtained allowed the visualization of 14 indicators and 55 variables; which constituted the basis for calculating the General Sustainability Index (GSI) of coffee agroecosystems (Zinck *et al.,* 2005), calculated through the equation (Equation 2).

$$IGS = \frac{\sum_{i}^{n}(VI)}{VMI * N} \qquad (2)$$

Where:
VMI= maximum possible value of an indicator;
N= number of indicators.
Agro-ecological zoning.

Agro-ecological zones were established taking into account similar characteristics: climate, soil, socio-economic and biophysical potential for coffee production in the agro-ecosystems selected and evaluated, through indicators, at the diagnostic stage. The establishment of the agro-ecological zones was carried out based on a cluster and discriminant analysis, to classify the agro-ecosystems, according to the values shown by the set of indicators; with the intention of establishing criteria of the Main Agro-ecological Structure that characterizes the farms producing *C. canephora* in the province. The statistical package InfoStat (2016) was used for this purpose.

Agro-ecological potentials and proposal of alternatives

The agro-ecological potential of coffee agroecosystems was defined, based on their characterization, with the purpose of establishing management alternatives aimed at achieving a more efficient operation of these, based on the application of agro-ecological principles (Nicholls *et al*., 2015).

RESULTS AND DISCUSSION

Socio-economic, environmental and political-institutional characterization of the province's coffee agro-ecosystems Uige

Social actors qualify access to and quality of health and education services as acceptable. In this regard, 61 % indicated that they get sick little and 72 % that specialized health services are located up to 45 km away. However, as a result of the long period of armed conflict in Angola in the 1970s, there is a disproportionate amount of family composition. In this regard, 14 % of the farm owners surveyed are widows and the main workforce, in 85.5 % of the farms, is in the family, mainly children and young people (29 %).

Agricultural production for self-consumption is developed in small gardens with little significant impact on the family economy, which is limited by the scarcity of water for irrigation, labor, resources and appropriate technologies, which make the productivity of the agro-ecosystem very deficient. This has a negative influence on the consumption levels that each member of the family must have.

Furthermore, the agricultural products harvested are dependent on the rainy months for their growth and development, which is in accordance with the criteria of Rogé *et al.*, (2017), Katlyn (2013) regarding the actions of climate on the productive results of agricultural crops in this type of agro-ecosystems. The consumption of agricultural products is stationary and producers do not practice methods of conservation of surplus production, negatively affecting family food security.

The shading species of *C. canephora*, present in the agroecosystems, constitute agroforestry systems that provide secondary production to the family, with a high percentage of use for consumption and sales; as well as, characterize these agroecosystems by a great diversity of components with high utility, if correctly used. The most representative are: fruits, roots, tubers, firewood, coal, and to a lesser extent, grains and vegetables.

In many cases, producing families sell the ripe cherry coffee harvest directly in the field, per unit of volume, because there are no processing plants nearby. However, commercialization is made difficult by the poor condition of the transportation routes, which leads to other small producers having to process, with many limitations, their dry harvest and sell the coffee in dry black cherry. This aspect has an impact on the low income that families receive and diminishes the motivation to exercise good agricultural practices and to better use the potential that the diversification of their farms offers them.

On the other hand, during the visits made, it was observed that the soil cover depended on the volume of fallen leaves from the coffee plants and the shading species. Also, the results showed that the use of the residuals, resulting from the coffee processing, in the recycling of nutrients within the system is still insufficient. In addition, the use of soil improvement techniques and the production of organic matter is limited.

As for the diversity of species of shade plants associated with coffee plants, a richness of 12 species was recorded. The species with the highest proportional abundance were banana (22,09 %), avocado (15,91 %), oil palm (15,68 %) and mango (9,98 %), of the total number of registered individuals; where, 99 % of the owners indicated that these species are used for food and marketing, with the aim of increasing household income.

However, the farms in each location could be differentiated, according to the number of associated shading species *C. canephora*. According to the results of direct sampling, they use four to seven species. In Songo (51 %) and Mucaba (49 %), it was very common to find farms with four species and others with five, six or seven species.1) (Figure 2).

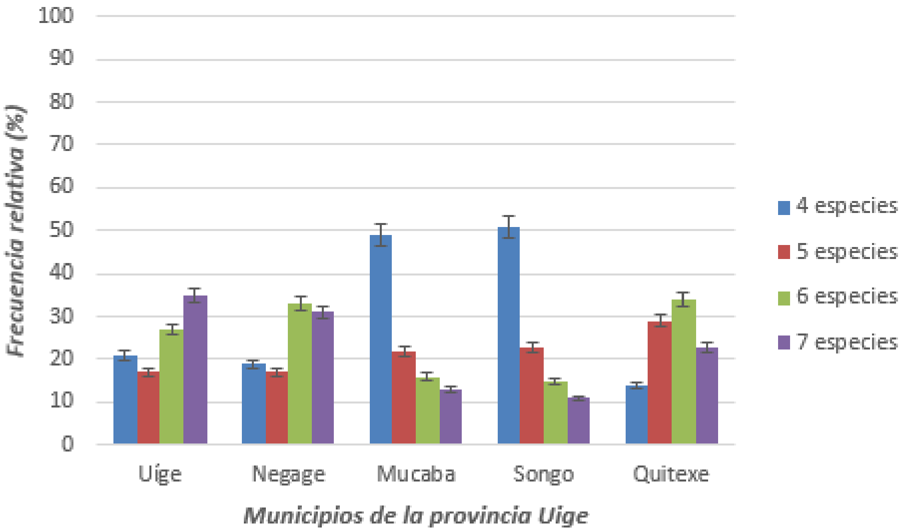

Figure 2.- Relative frequency of the number of shading species associated with *Coffea canephora* on farms in municipalities in the province Uige, Angola

The farms with the greatest diversity of shading species were registered in Uige, Negage and Quitexe. It was very common to find farms with seven species in Uige (35 %) and Negage (31 %); as well as, with six species in Negage (33 %) and Quitexe (34 %). These results were considered positive and suggest that coffee growers are developing their plantations in diversified agro-ecosystems (Figure 2).

However, in 23 % of the farms in these territories, biodiversity is not controlled, and forest plant species are found inside the coffee plantations that hinder the growth and development of the coffee plants. These can be replaced by others that have greater functionality in the agro-ecosystem; both for the contributions to the economy of families, as for the provision of ecosystem services.

In this regard, the diversification of tree species associated with coffee is an agro-ecological practice that provides ecosystem services such as shelter and habitat for wildlife and beneficial organisms, biological corridors, carbon sequestration, microclimate regulation and nitrogen fixation, in addition to being another source of income for farmers (Meylan *et al*., 2013; Bacon *et al*., 2014).

On the other hand, the Shannon-Wiener index (H'), was less than two and suggests that *C. canephora* agroecosystems in each municipality have a relatively low species diversity, on average (Table 1).

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Table 1.- Diversity of shading species associated with *Coffea Canephora* on farms in municipalities in Uige province, Angola, calculated using the Shannon-Wiener index (H´)

Municipalities	H´
Uíge	0,8694
Negage	0,8429
Mucaba	0,8427
Songo	0,8340
Quitexe	0,8690

Therefore, the management alternatives of the coffee agroecosystems should take into account an integral conception for the increase of the biodiversity and the conformation of a more complex system of coffee production; which can be achieved according to the criteria of (Contino *et al*., 2018).

The diagnosis carried out showed that the General Sustainability Index (GSI) is similar in the behaviour of the main indicators evaluated (Figure 3).

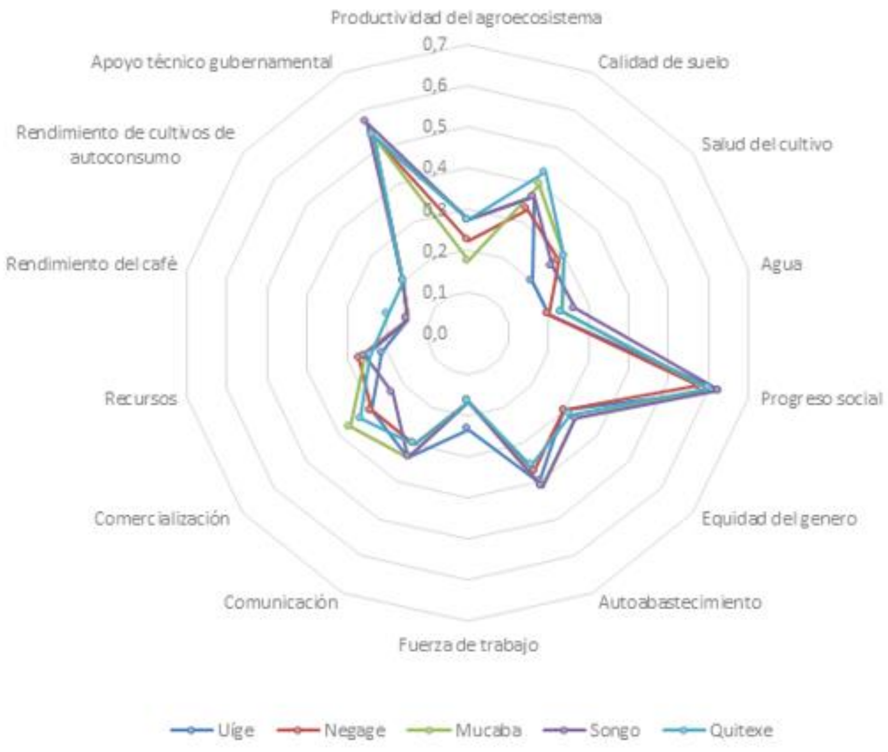

Figure 3. - General Sustainability Indicators, according to the indicators evaluated in municipalities of the province Uige, Angola

In general, the results showed unsustainability in the five municipalities, reaching values of (*IGS<0,6*), which according to Zinck *et al.*, (2005), is the beginning of the approach to sustainability. They also demonstrated the validity of the indicators used to characterize the environmental, economic, socio-cultural and political-institutional situation of *C. canephora* production in the province.

This study indicated the need to modify the current focus of the actions aimed at solving the problems that affect the productive results of *C. canephora* in the province, which should be solved from the perspective of greater use of agro-ecosystem resources, increasing functional biodiversity as a starting point for achieving agro-ecological development of coffee production in these territories.

Agro-ecological zoning

In order to expose the differences between coffee agroecosystems, it was important to evaluate the variables that define the behaviour of the proposed indicators in the agroecological dimensions. In this regard, these indicators recognized the structure of six groups of agro-ecosystems, according to the cluster analysis, with a coefficient of co-phenetic correlation of 0,895, a value of the statistic that is considered reliable when exceeding 70 %, which implies different agro-ecological management in each group (Figure 4).

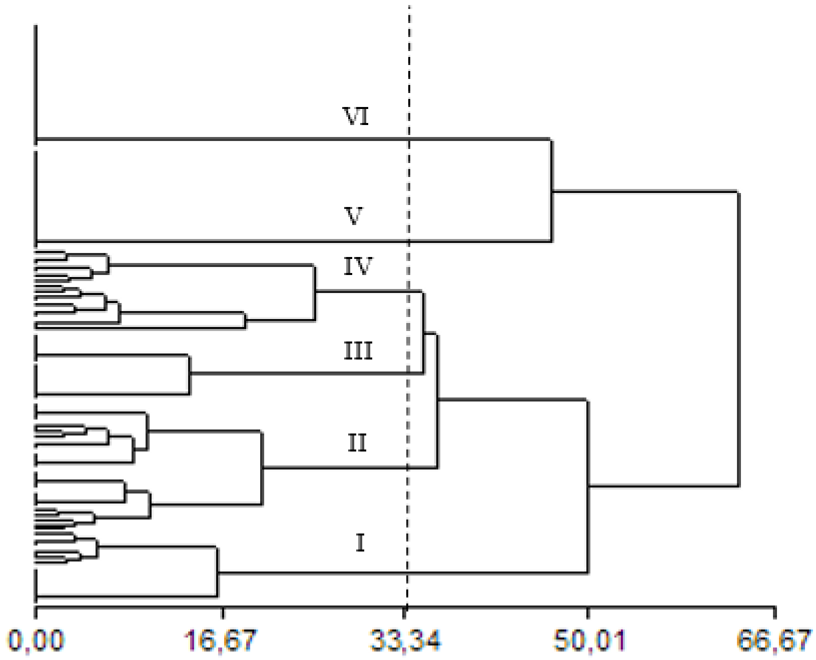

Figure 4. - Dendrogram of the structuring of selected agro-ecosystems based on the proposed indicators

Reference line in black dashes

The design of *C. canephora* agroecosystems in the province reflects that they are composed mainly of the following subsystems: coffee plants, shade trees, forest plantations, self-consumption, cover plants, animal production and economic management. However, when characterizing the agro-ecosystems, it turned out that these have similarities in some cases and differences in a great part of the evaluated indicators, where the characteristics that define a group, can be observed in any of the studied municipalities. All this reflects that the management of the plantations, of the labour and financial resources in each territory is not the same. Furthermore, they reflected that there are problems with the energy flow between the different components of these, which justifies a new specific design, determined by the socioeconomic and environmental context that characterizes each agroecosystem (Nicholls *et al*., 2015; Rosset y Martínez, 2016).

The indicators related to: agricultural pulping and industrial yields; topography; structural composition of shade; land use and tenure; soil agro-productivity; and traditional knowledge, were those that allowed discrimination between each group of farms; since the discriminating function indicated values of $P<0.001$. Therefore, they were the most useful to characterize the Main Agroecological Structure of the coffee agroecosystems of the province Uige.

Accordingly, there is a lack of initiatives to reduce poverty and food insecurity levels, which are related to the limited knowledge that families have about the importance of diversifying production. Therefore, it will be necessary that the strategies are focused on raising the levels of productivity and rational use of resources available in the agroecosystem, which will result in greater ecological and cultural resilience of the agroecosystems of *C. canephora* in the province and consequently, in the sustainability demonstrated by them (Cuevas *et al*., 2019).

Determination of agro-ecological potentialities and proposal of alternatives

There are several agro-ecological potentialities that define the sustainability of the coffee agro-ecosystems in the province of Uige, among which are:

- Presence of coffee agroforestry systems with great plant diversity
- Relief conditions, height above sea level and microclimates created that favor the quality of harvested coffee.
- Existence of favorable soil and climatic conditions for the growth and development of *C. canephora* plantations.
- Coffee culture. It reflects potentialities to increase the productive results of these systems and the development of organic coffee production.
- Interest of producers to remain linked to coffee production.
- There are agroecosystems with favorable integral results that can serve as an example in agricultural extensionism.

However, it was considered fundamental to implement alternatives aimed at the sustainable development, based on agro-ecological principles, of coffee production in the province:

- Increase biodiversity on *C. canephora* farms, based on the food self-sufficiency of the producing families.
- Increase agricultural extension programs by incorporating agro-ecological alternatives into the production system.
- The implementation of integrated management practices for coffee plantations (cultivars and clones, density, pruning and shading plants), to increase yield potential, quality and competitiveness in the market.
- The implementation of organic alternatives to raise the nutritional levels of the plantations and the improvement and conservation of the soils.
- The application of agro-technical measures aimed at the sealing of the plantations and their renovation.

- The improvement of the productive infrastructure and of the benefit of the coffee, as well as, of the roads that make difficult the transfer of the harvest.

In general, the study was useful to characterize and classify the PLA of *C. canephora* agroecosystems, providing knowledge of the particular characteristics of each farm and its ecosystem environment, which constitute the basis for the redesign of the coffee agroecosystems of the province; which will allow coffee growers to make adjustments in their agroecosystems, stimulating: the connectivity of its components, energy flows and the functionality of biodiversity.

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Conflict of interests:
The authors declare not to have any interest conflicts.

Authors' contribution:
The authors have participated in the writing of the work and analysis of the documents

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