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Original article

Crop diversification in a cocoa agroforestry system in the Jamal massif, Baracoa municipality

Diversificación de cultivos en un sistema agroforestal cacaotero en el macizo del jamal, municipio Baracoa

Diversificação de culturas em um sistema agroflorestal de cacau no maciço de Jamal, município de Baracoa

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ABSTRACT

The increase in agricultural biodiversity is one of the keys to success. In the efforts of achieving a sustainable agriculture, the fundamental motivation in this research, was to evaluate the impact of the diversification of short-cycle crops in a System Agroforestry of *Theobroma cacao* L., in the Jamal massif, Baracoa municipality, on Sialitic Brown soil,

undulating relief and average slope of 15 percent. Taking an extensive bibliographical review as a starting point, the materials and methods were established, selecting two plantations located in the same edaphoclimatic conditions. In one of them, alternatives were applied for the diversification of crops in the cocoa agroforestry system (polyculture) and in the other the normal conditions of the management of monoculture plantations were maintained. Plantings were carried out during the period from February 2017 to the first semester of 2018, in the Jamal cocoa massif, Baracoa municipality. Short cycle crops used: Zea *mays* L. (corn), *Cucurbita pepo* L. (pumpkin), *Cajanus cajan* (L.) (pipe pigeon pea) Huthy , *Colocasia esculenta* (L.) Schott. (malanga). The productive efficiency of intercropping crops was compared to those carried out in monoculture, for which the equivalent index of land use (IET) was used. Coinciding with several expert researchers on the subject, it was validated that polycultures achieved greater efficiency than monoculture crops by presenting IET values greater than unity (1), without affecting the main crop and its yields. It was shown that associating short-cycle crops with cocoa cultivation allows obtaining various crops, increasing agricultural production, generating additional income for the producer and improving their food sovereignty, factors that positively impact the sustainability of the cocoa agroforestry system.

Keywords: Cocoa; Agroforestry system; polycultures; Efficiency.

RESUMEN

El incremento de la biodiversidad agrícola es una de las claves del éxito, en el empeño de alcanzar una agricultura sustentable, la motivación fundamental en la investigación realizada, la cual se planteó como objetivo evaluar el impacto de la diversificación de cultivos de ciclo corto en un Sistema Agroforestal de *Theobroma cacao* L., en el macizo del Jamal, municipio Baracoa, sobre un suelo Pardo Sialítico, relieve ondulado y pendiente promedio del 15 %. Teniendo como punto de partida una amplia revisión bibliográfica, se establecieron los materiales y métodos, seleccionándose dos plantaciones ubicadas en las mismas condiciones edafoclimáticas. En una de ellas se aplicaron alternativas para la diversificación de cultivos en el sistema agroforestal de cacao (policultivo) y en la otra se mantuvo las condiciones normales del manejo de las plantaciones en monocultivo. Las siembras se realizaron durante el periodo desde febrero del 2017 hasta el primer semestre del 2018, en el macizo cacaotero del Jamal, municipio Baracoa. Los cultivos de ciclo corto utilizados: Zea *mays* L. (maíz), *Cucurbita pepo* L. (calabaza), *Cajanus cajan* (L.) (frijol gandul) Huthy, *Colocasia esculenta* (L.) Schott. (malanga). Se comparó la eficiencia productiva de las siembras de los cultivos intercalados frente a las realizadas en monocultivo, para lo cual se utilizó el índice equivalente del uso de la tierra (IET). Coincidiendo con varios investigadores expertos en el tema, se validó que los policultivos alcanzaron mayor eficiencia que las siembras de monocultivos al presentar valores de IET superiores a la unidad (1), sin afectarse el cultivo principal y sus rendimientos. Se demostró que asociar cultivos de ciclo corto al cultivo de cacao, permite obtener diversas cosechas, incrementar las producciones agrícolas, generar ingresos adicionales al productor y mejorar su soberanía alimentaria, factores que impactan positivamente en la sostenibilidad del sistema agroforestal cacaotero.

Palabras clave: Cacao; Sistema agroforestal; Policultivos; Eficiencia.

RESUMO

O aumento da biodiversidade agrícola é uma das chaves do sucesso, no esforço para alcançar uma agricultura sustentável, a motivação fundamental nas pesquisas realizadas, que visavam avaliar o impacto da diversificação das culturas de ciclo curto em um sistema agroflorestal de Theobroma cacao L., no maciço de Jamal, município de Baracoa, em um solo sialítico marrom, relevo ondulado e declive médio de 15%. Com base em uma extensa revisão bibliográfica, os materiais e métodos foram estabelecidos, selecionando duas plantações localizadas no mesmo solo e nas mesmas condições climáticas. Em uma delas, foram aplicadas alternativas de diversificação de culturas no sistema agroflorestal do cacau (policultura), e na outra, foram mantidas as condições normais de manejo de monoculturas. As plantações foram realizadas durante o período de fevereiro de 2017 até a primeira metade de 2018, no maciço de cacau de Jamal, município de Baracoa. As culturas de ciclo curto utilizadas foram: Zea mays L. (milho), Cucurbita pepo L. (abóbora), Cajanus cajan (L.) (ervilha de pombo) Huthy, Colocasia esculenta (L.) Schott (malanga). A eficiência produtiva do cultivo entre culturas versus monocultura foi comparada utilizando o índice de uso da terra equivalente (ETI). De acordo com vários pesquisadores especialistas no assunto, foi validado que as policultura alcançaram maior eficiência do que as monoculturas ao apresentar valores ETI superiores à unidade (1), sem afetar a cultura principal e seus rendimentos. Foi demonstrado que a associação de culturas de ciclo curto ao cultivo do cacau permite obter colheitas diversas, aumentar a produção agrícola, gerar renda adicional para o produtor e melhorar sua soberania alimentar, fatores que têm um impacto positivo na sustentabilidade do sistema agroflorestal do cacau.

Palavras-chave: Cacau; Sistema Agroflorestal; Policultura; Eficiência.

INTRODUCTION

Currently, agricultural production is based on a model that simplifies agroecosystems with monocultures; despite the fact that biodiversity is necessary for the food security of the world population (Food and Agriculture Organization of the United Nations (FAO, 2018). The consolidation of this reductionist approach and highly dependent on chemical inputs has contributed to soil deterioration, water contamination and even affected human health, modern agriculture being characterized by its great uniformity (Sarandón, 2022).

Agricultural research has traditionally been oriented towards monoculture, and work on intercropping is limited. Given the growing demand for food and the current need to practice sustainable agriculture, multiple crops are a viable alternative due to their production potential and efficient use of resources.

Hence, agroforestry systems (AFS) constitute an alternative to the problem of monocultures; allow them to be displaced because they involve the combination of forest trees with other crops, or with domestic animals, or both. So, it turns out that, the production per unit area improves, while the principle of obtaining sustainable yields is respected (Torres *et al.,* 2014). In the same way, through the integration of trees on farms and agricultural landscapes, production is diversified and sustained to increase the social, economic and environmental benefits of farmers at all levels (Mata, 2012) cited by Mata (2018).

In this context, several studies have demonstrated the benefits of diversity in agricultural fields, in relation to the increase in plant productivity (Ebel *et al.,* 2017; Rodríguez, *et al.,* 2019), income improvement (Aguirre, 2012), crop association as an alternative for the development of sustainable agriculture (Tamayo and Orihuela, 2022), water optimization and increased soil fertility (Navas Panadero *et al.,* 2020), family well-being (Vásquez González *et al.,* 2018) and the promotion of sustainable social and environmental practices (Vogt, 2019).

It is necessary to demonstrate the benefits of this type of innovation in an integral way; as well as the main types of arrangements that can be identified in the rural sector. Therefore, the need to evaluate specific ways of cultivating for these crop patterns has been discussed

(Sarandón and Chamorro, 2003) and based on the evidence found, the possibility of identifying new combinations of species for associated crop plantings has been established. For this reason, the present investigation, conducted during two years, had as an objective to evaluate the impact of the diversification of short-cycle crops in an Agroforestry System of *Theobroma cacao* L., in the Jamal massif, Baracoa municipality, Guantánamo province, Cuba, on Sialitic Brown soil, undulating relief and average slope of 15 percent.

MATERIALS AND METHODS

The research was carried out in areas belonging to the Jamal cocoa massif, specifically in the Basic Cooperative Production Unit (UBPC) "José Maceo Grajales". The cooperative is located in the popular homonymous council, corresponding to the Baracoa municipality in the Guantanamo province, Cuba, located at 20°16'34.65" north latitude and 74°25'32.35" west longitude, at 23 meters above sea level. It was developed in a 23-year-old cocoa plantation, with yields of 0.45 t. ha^{-1} in undesigned agroforestry systems, on a soil with Sialitic Brown grouping, (Hernández *et al*., 2015), undulating relief and average slope of 15 percent.

For the research, we worked on a cocoa plantation in production established and rehabilitated through a spatial arrangement of 3 x 3 m combined with shading forest trees, mainly *Gliricidia. sepium* and *Samanea saman.*

Eight rows of cocoa with eight plants were chosen for a total surface area of 400 $m^{2.}$ A *quasi- experimental* design was established with two treatments (with and without treatments), each treatment consists of six plants in the same row without random distribution. At each end of the treatments, a border plant and a complete row were left between the treatments under study (Figure 1).

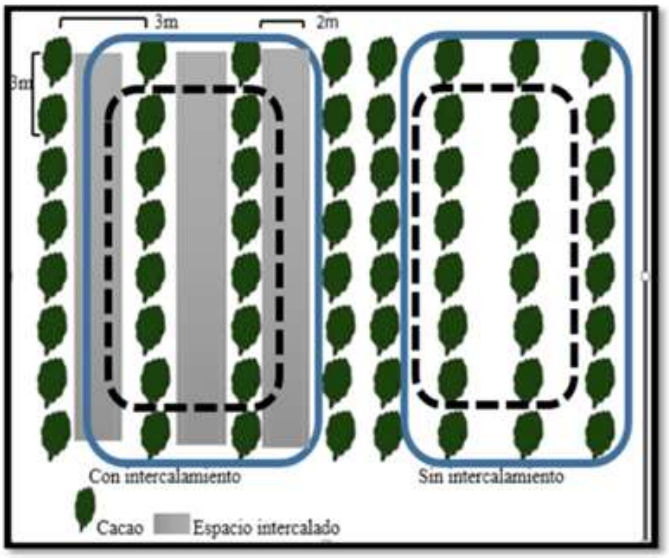

Figure 1. - Arrangement of *Theobroma cacao* L.

Way to implant intercrops in cocoa plantations

The intercropping of short-cycle crops began in February 2017, as can be seen in (Table 1), with the distribution of crops over time during the development of the experiment, concluding in the second semester of 2018.

Table 1. - Planting date short-cycle crops interspersed in *Theobroma cacao* L. plantation

Crops	Year 2017	Year 2018
Theobroma cacao L.	Established	Established
Cucurbita pepo L.	February- May	February- May
Zea *mays* L.	May - August	May - August
Cajanus cajan L.	May–December	May–December
Colocasia esculenta (L.)	March-December	April-December

The planting of the short-cycle crops were interspersed with the cocoa crops with spatial arrangements according to the traditional method of the locality (Figure 1). The spatial arrangements were the following: for maize, one meter between rows (two rows of maize between rows of cocoa) and 0.30 m between plants and between two and three grains per nest. For pumpkin planting, three seeds per nest (a single row) were deposited at a distance of 1.50 m between the cocoa lanes and 1.50 meters between plants and manually directing their guides through the lanes, avoiding their penetration and coverage to the surface belonging to cocoa plants.

Pigeon pea was planted every 1.50 m between plants and 1.50 m from the cocoa rows that coincide with the center of the streets within the plantation. The taro was planted at a distance of 0.90 m between rows (two taro rows between rows of cocoa) and 0.45 m between plants by the manual method.

The monoculture short-cycle crops were planted in an adjacent area of 400 m^2, according to the same period and received the same cultural care as at the time of intercropping.

Cultural tasks carried out in the intercrops

The cultural tasks for each crop were carried out according to the characteristics of each one. None of the crops underwent a pest management work, since there were no affectations that required phytosanitary labor. After the placement of the seeds and the covering, the soil moisture was dependent on the rains, taking into account that these short-cycle crops are obtained in the mountains under dry conditions. No fertilizers were applied.

The control of weeds for the cultivation of corn was carried out in its critical stage, and for the work of squash, they were managed until the field was covered by the foliage. When cultivating taro, it was necessary the weeding and the hilling. In the management of the pigeon pea plantation, weed control was done before the plantation closed, by the manual method.

Evaluations carried out in the intercrops

In order to know the efficiency of short cycle crops interspersed with cocoa, the Land Equivalent Index (Vandermeer, 1989) was used, where the sum of the yields of the individual IET of each crop product of the combinations will give the total IET (acronym in Spanish). That Total Index is used to compare the productivity of polycultures versus monocultures in a given area: $IET=\sum_{n}^{i} pp/pm$, where pp is polyculture production and pm is monoculture production.

It is necessary to underline that the individual IET is the result of the value of the relationship: polyculture production (pp) between monoculture production. When ETI is > 1.0 (for two crops or more), polyculture is economically efficient; < 1, means that the polyculture did not produce more than the monocultures in terms of unit per area; values = 1, it means that the unit per area is the same in both production systems.

Then the $IET = IET_1 + IET_2 + IET_3 + ET_4$ are the IET of each crop. The production value will correspond to the sum of the production values of the total crops participating in each planting, plus that of cocoa. The Land Equivalent Index (IET) or Equivalent Land Use (UET) as it is also known, provides a measure of yields achieved by establishing two or more crops intercropped, comparing these results with the same crops, but planted individually in a certain area in the form of a monoculture. The (IET) is a method used when associated crops are established with the purpose of obtaining a parameter that indicates the maximum productivity of the area.

The IET is generally used to assess the agronomic, biological and economic efficiency of polycultures, making these alternatives available to producers, which will affect their income and food security; another no less important aspect is the incidence of pests, referring to the consulted literature that the use of this system decreases the occurrence, and/or the control of harmful insects.

The productive efficiency of the system will be achieved when the values of all the added productions exceed the unit, an indicator that the polyculture is efficient from the economic dimension. The indicators evaluated were: yield of short-cycle crops and of the two cocoa harvests of the years studied, in t. $ha^{-1.}$

Economic evaluation of intercropping in cocoa cultivation

The economic analysis was carried out from the calculation that included the expenses and income incurred in intercropping, to obtain the net profit, according to SAGARPA (2015). The analysis was carried out considering the prices of the products in force during the experimental period.

RESULTS AND DISCUSSION

The Land Equivalent Index (LEI) is used as a measure of intercropping efficiency. Table 2 shows the results of the yields of the intercrops in the cocoa crop and their respective Land Equivalent Index (IET) (Table 2).

Table 2. - Yield of the intercropped crops and determination of their respective individual LEI of the crops

Crops annual in monocultures	Monoculture Yield (t ha $^{-1}$)	Polyculture yield (t ha $^{-1}$)	individual TIs of annual crops (t ha $^{-1}$)
Corn	0.335	0.157	0.468
Pumpkin	0.384	0.187	0.486
taro	0.284	0.112	0.394
pigeon pea beans	0.270	0.107	0.396
Totals	1,273	0.563	1,744

Source: Prepared by the authors based on information collected at the José Maceo Grajales UBPC.

In this regard (García-González *et al.*, 2015) disclose that crop rotation and polycultures are developed in order to stimulate the natural fertility of the soil, control pests, restore productive capacity and obtain a higher IET, for what these practices can increase yields in most economically important crops.

It is opportune to point out, regarding the pests, that control measures did not have to be taken in the investigation carried out, which corroborates what was stated by the referenced authors. Reaffirmed by (FAO, 2018) which considers that cultivation associations are an important component in the use of biodiversity for the management of harmful insects and microorganisms, which constitutes a crucial aspect in agriculture, mainly because it can minimize the use of agrochemicals by promoting biological control.

As there are different species of plants within the same area, the variety of flowers generated by the crops attract many natural enemies, managing to maintain a better natural control of them. At the same time, when pests are controlled biologically in a high percentage, the use of pesticides decreases considerably, therefore, polycultures have that economic advantage that is very important for producers.

According to the analysis of the average yields of intercropped short-cycle crops and the determination of their respective Land Equivalent Index (IET), the yields of monoculture crops were much higher than associated crops. The yields of the crops studied in monocultures were at the level of the average production of the locality, with the exception of the pigeon pea, which has no reference, which is recommended to investigate.

All this seems to confirm that, in polycultures, productivity per area is lower than the production of monocultures, considering that plant densities are high in monocultures.

However, the sum of the yields achieved in polycultures guarantees a higher production compared to monocultures.

Hence, the results show that associated crops can become a viable alternative for small cocoa producers. There are several advantages of this system, among which we can highlight: the diversification of production, and the maximum use of the resources present in the plots. This practice is very useful since it tends to maximize production (Funes-Monzote, 2009). On the other hand, polycultures also have a positive impact on the suppression of weeds, which promotes less competition for nutrients between them and crops.

Of these treatments, the combination of corn and pumpkin with the main crop generated the highest Land Equivalent Index, meaning that, it turned out to be the most productive polycrop. In other words, as can be seen in Table 2, pumpkin was the crop with the best behavior followed by corn, both with yields that guarantee economic efficiency.

In relation to the corn crop, the yield was higher than expected, even though it was not as high; but it was one of the short-cycle crops with the best productive performance, together with pumpkin, especially in the first year.

In contrast to the above, for both crops the yields were not favorable the following year. That happened especially with the corn crop in the second repetition of the treatment in 2018, since it did not obtain the productive potential compared to the previous year, as was also the case pumpkin, to a lesser extent.

In the second stage, the incidence of the cocoa shade could have had some influence, due to the sprouting of new branches in the cocoa agroforestry system. It is highlighted, that there was a mutually positive interaction between these crops and cocoa, showing good coexistence and economic and ecological viability. It is valid to state that there is no reference to the existence of some effects between these crops in their association with the main crop: cocoa.

On the other hand, taro and pigeon pea had the lowest efficiency with similar values. Nevertheless, they had favorable yields and good physiological complementation with respect to cocoa cultivation as shown in Figure 2, for taro cultivation.

Figure 2. - Representation of the cultivation of malanga + cocoa intercropped in the agroforestry system

Therefore, including the cultivation of *Colocasia esculenta* L. and *Cajanus cajan* L. in diversification, it is not considered a negligible strategy. On the contrary, due to the contemporary trend of increasing agrobiodiversity in production systems, as well as diversification, it is a practice to increase agricultural production and improve the food sovereignty of producers.

On the other hand, it should also be clear that there is a need to adapt polycultures to the challenges of the present, taking into account the proper selection of the same by the producer, the characteristics of the productive area, the management requirements, customs and traditions, inter alia.

Intercropping competition can influence, depending on the age of the cocoa crop, type of crop, agronomic management and the spatial arrangements that are made. From where, with good agronomic practices in the intercropping, number of plants according to the planting distances of the main crop, and with good soil management, it is possible to obtain agricultural products, thus increasing the economic and environmental efficiency of the cocoa agroforestry system, and increase the quality of life of producers.

Establish agricultural crops in time and space, considering the environmental conditions that each crop needs, the cultural management requirements of the crops when they are developed intercropped, as well as the management needs for the entire cocoa agroforestry system and additional actions such as soil conservation or improvement of the microclimate of the agroforestry system, with the regulation of shade and other very specific forms in the cocoa farms, increases the efficiency in the use of land and the productivity of the agroecosystem studied.

Within this framework, the importance of these results in general is significant, since they are contributions of food products that are normally no longer produced under monoculture conditions and that can represent an income for the producer.

The total (IET) registered a value of 1.74 for polycultures, being greater than the area unit (Table 2), which indicates that these systems are more productive than monocultures per unit of occupied land (Jiménez *et al*., 2017). This expresses that the area planted with monocultures would need to be 74 percent greater than that occupied with polyculture, to produce the same (Gliessman, 2002). In other words, it indicates that monocultures require 74 percent more area to obtain the same yields as polycultures. It also represents that the polyculture system had an over-yield of 74 percent more production per unit area than the monocultures separately.

Therefore, 1.74 ha of the same crop is needed to obtain the same productivity of one hectare of polyculture. Indicates the total area required to produce the same amount of each crop when planted separately.

Therefore, the results obtained show that the intercropping of short cycle crops within the spaces of the perennial crop (cocoa), provides an IET that exceeded the value of the unit by a considerable percentage. This calculation also reveals how a species uses the spaces in relation to the other, so it is considered that values greater than one (1) indicate symbiosis of the species and less antagonism between them.

The results achieved are corroborated with studies carried out by (Ochoa, 2018) but, with a mixture of bean varieties associated and interspersed with corn in Ecuador, which have reported Equivalent Land Index values greater than one. In the same line Ebel *et al*., (2017) consider that polycultures generate greater efficiency in agronomic terms, considering the individual effect of each of the components and production conceived as a whole, obtaining a greater overall response than monoculture.

In this sense, the researchers (Ordóñez *et al.*, 2018) point out that arrangements based on cocoa (Theobroma *cacao L.)*, coffee (Coffea *arabica)* or plantain (Musa ABB), in association with other crops, can be identified on the farms of small producers in Colombia, Ecuador and Peru. In those countries, local producers defend diversification in cocoa agroforestry systems, because it allows them to improve their diet, conserve agrobiodiversity and maintain cultural identity.

On the other hand, the results obtained show a better efficiency in the use of the land by providing better use of the soil, which later represents a gain from the economic point of view, since the average value is equal to 43 percent of all the IET determined in each crop.

At the same time, the individual IETs provided an important use of the land surface during two years, favoring the obtaining of higher income and profits in economic terms, once the investment expenses were analyzed.

For the results of this work, since four short-cycle crops have been used in two years and two cocoa harvests, the index is as follows:

IET = ∑ i n (IET r 1 + IET r 2) + (IET 1, 2, 3, 4) where r 1 and r 2 are the values of cocoa crops in t. ha $^{-1}$. IET 1, 2, 3, 4 are the values of the harvests of the short-cycle crops.
For the two years, the value of the IET would amount to the ∑ of the two years, that is:

- IET = ∑ [IET cacao] + [IET cultivos ciclo corto]
- IET = 0,13 + 0,32] + [0,468 + 0,486 + 0,394 + 0,396]
- IET = 0,45 + 1, 74
- IET = 2,19

The IET values of these crops represent a considerable contribution to the agroforestry system compared to a perennial crop such as cocoa. In the case studied in 2017, after Hurricane Mathew in October 2016, at the UBPC level, a very low productivity was reached, 0.07 t. ha^{-1}, which was far from exceeding the average of the Baracoa municipality, of 0.40 t. ha^{-1}.

Subsequently, the combination of these crops interspersed in the cocoa plantation and alternating during the year, could be a recommended option for farmers, who start promotions, renovation or rehabilitation and even in those spaces that for different reasons are not used in cocoa agroforestry systems.

Regarding polycultural arrangements (Vásquez *et al.,* 2018) consider that it is possible to identify various types of arrangements in territories with a predominance of peasant agriculture. Likewise, Aguilar *et al.* (2019) concluded that, in tropical agroecosystems, polycultures are more efficient in the use of land in relation to monocultures of the basic species when they are managed under the organic agriculture approach. That indicates that the ecological interrelations occurring in multiple crops benefit the integral system and contribute to the sustainable and safe production of corn, beans and pumpkin. In rural areas, it is common to mix bean varieties in association with other crops to reduce the spread of pests and diseases and generate food in different seasons.

On the other hand (Salgado-Mora *et al.,* 2018) indicate the main combinations in cocoa and coffee, in association with other agricultural, fruit and various species of timber trees. Underlining (Vásquez *et al.,* 2018), its importance for being associated with the cultivation of a wide diversity of edible plants and providing a more varied diet to producers throughout the year. Similarly, authors such as Alvez and Alayón (2020); Escobar *et al*., (2020); Navas *et al.* (2020) reveal that the implementation of associated systems can become an adequate alternative to face adversities. Highlighting that the research carried out in this framework makes visible the benefits of various types of arrangements by recording: (i) greater biological diversity in the soil; (ii) recovery of degraded lands and reduction of erosive processes; (iii) increase in organic matter; (iv) increase of macro and micronutrients in soil by association with leguminous crops and tree species; and (v) better efficiency in the use of water and solar radiation.

To sum up, these cultivation associations are currently an important component to intensify production and at the same time improve agroecological conditions, farm biodiversity, soil protection and contribute to a greater economic sustainability of the producer.

Economic analysis

The economic analysis of the result is presented in Table 3.

Table 3. - Economic analysis of the intercropping of annual crops in cocoa

Crops	Performance (t/ha^{-1})	Bills ($/ha^{-1})	Income ($/ha^{-1})	Utility ($/ha^{-1})
Corn	0.157	401	1192.46	791.46
Pumpkin	0.187	276	486.96	210.96
taro	0.112	395	1033.26	638.26
pigeon pea beans	0.107	100	587.94	487.94
Total	0.563	1172	3300.62	2128.62

Source: Prepared by the authors based on information collected at the José Maceo Grajales UBPC.

When analyzing and evaluating the interactions between the different economic actors of these results on the interspersed crops in the cocoa crop, expenses were generated for the crop system in the work of planting and cultural care. However, an income generated by the increase in production in MN of $3,300.62 $/ha was obtained, a profit or profit with a value of 2,128.62 pesos per hectare.

In this context, the total cost of establishing polycultures is increased by a greater investment in inputs such as seeds and the cost of labor, despite which, when the global quantification of the production obtained is carried out, it will favor the obtaining higher income and profits than in monoculture.

When comparing these evidences, Aguirre (2012) argues that in the type of arrangement implemented, increases in income between 10 and 150 percent can be identified. At the same time, the aforementioned author recorded revenues of more than 10 percent when corn was intercropped with cowpea beans (Vigna *unguiculata)* and sweet potatoes (Ipomea *batatas)* in Uruguay. Likewise, Aguirre (2017) when economically evaluating the corn-bean-pumpkin system in Chiapas-Mexico, obtained net benefits that far exceeded the corn monoculture (even by more than 100 percent).

Indeed, when analyzing research related to the corn-bean-pumpkin association (corn fields) in Mexico and Uruguay, the importance of polyculture plantings compared to monoculture is evident.

From all this, it can be deduced that, in the case of these intercrops, the experiences obtained have allowed increasing income on the farm. In the same way, it is an opportunity to increase the recycling of the organic matter that remains in the crop residues of the intercrop.

Finally, when any crop is intercropped with cocoa, agronomic management must be carried out independently of each crop, with the purpose of reducing the possible competition of the crop intercropped with cocoa, and thus obtain additional income without affecting fundamental production.

CONCLUSIONS

The results achieved show that the diversification of short-cycle crops in a Cocoa Agroforestry System constitutes a feasible alternative to achieve sustainable agriculture, reflected in the best use of natural resources, increased biodiversity, ecological management of pests and diseases. That added to the increase in the income of the producers, guarantees the sustainability of the cocoa agroforestry system.

The interspecific association of annual and biennial crops will guarantee greater economic and environmental efficiency of the system, by positively impacting on the increase of the productive, economic and environmental results of the cocoa agroecosystem.

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