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Promotion of sustainable development through guadua (*Guadua angustifolia* Kunth) in rural communities of Cundinamarca - Colombia

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Abstract: The Department of Cundinamarca in Colombia has a high potential for the production of Guadua (Guadua angustifolia Kunth), however, the inhabitants of rural areas are unaware of the multiple uses that can be obtained from this natural product. At the moment, it is used for basic constructions, handicrafts or for some work on the farm. It is a giant grass, a non-timber forest grass species, which, thanks to its physical properties of high resistance, rapid growth, CO2 capture, protection of soils and watersheds among other ecosystem services, has become an alternative to replace timber species. 250 people belonging to 12 municipalities in 4 provinces have been empowered, to whom a socioeconomic characterization was carried out, through a structured survey and social cartography. Through workshops, field trips, dialogue of knowledge, the transfer of knowledge on issues of environmental sustainability, project formulation, entrepreneurship and marketing were allowed. Thanks to the project, these people play the role of producers, processors and marketers of Guadua using appropriate techniques. In addition, they have been able to reflect and find in this element a contribution to the mitigation of climate change and the sustainable development of their communities.

Keywords: Bamboo; Knowledge transfer; Ecosystem services, SDGs, Sustainability.

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Introduction

In the midst of its biological diversity in Colombia, we find the Guadua (Guadua angustifolia Kunth) which is found in optimal conditions between 500 and 1,500 m. of altitude. The coffee zone is where there is a greater presence of this non-timber forest grass that is part of the landscape along with its coffee plantations. For this reason, the World Heritage Committee of the United Nations Educational, Scientific and Cultural Organization (UNESCO) inscribed it on the World Heritage List of the Coffee Cultural Landscape in 2011 (Coffee Cultural Landscape, 2023). According to the Ministry of Agriculture and Rural Development (MADR), in 2004 there were 35,027 hectares in the coffee zone, representing 84% of the national total (MADR, 2005). Therefore, it is an exceptional example of how human activity can be sustainable and harmonious with the environment. In addition, it is an example of how a culture can develop around an agricultural product, creating a unique and valuable cultural heritage.In the Department of Cundinamarca, Guadua is also present in the wild, however, the inhabitants of rural areas have little knowledge about the multiple uses that can be obtained from this natural product. They do not know that this non-timber grass has become an alternative to replace timber species due to its resistance. At the moment, it is used for basic constructions, crafts or for some tasks within the farm, some even consider it a weed or invasive plant. But people who want to use Guadua for a commercial activity encounter other difficulties because they need forest harvesting permits that generate extra cost, time and paperwork, discouraging industrial development and preventing the timely supply of raw materials (Londoño, 2011).Guadua producers, processors and marketers in the Department of Cundinamarca have low competitiveness compared to other regions of the country. Among its possible causes is the lack of knowledge of the productive and commercial potential, the weak links in this production chain, the lack of knowledge of the current regulations for silvicultural management and the scarce technology transfer for the transformation of Guadua in the region, together with the problems of violence historically presented in the cultivation regions, generating decomposition and instability in the social fabric. Thus, "the problems in Colombia that exacerbate the rupture of the social fabric are increasing and occur in various forms: common crime, administrative corruption, distrust in the authorities, and social inequalities" (Llinás & Anibal, 2022, p.160).Due to the above, the Secretariat of Science, Technology and Innovation (SCTeI) of the Government of Cundinamarca, in alliance with the Corporación Universitaria Minuto de Dios - UNIMINUTO, executed the project that aims to "Strengthen the competitiveness of the Guadua production chain through the development and implementation of two technological packages for the generation of value-added products based on activated carbon and laminated in the Department of Cundinamarca". 250 actors belonging to 12 municipalities in 4 provinces (Rionegro, Bajo Magdalena, Gualivá, Tequendama) were selected and socioeconomic characterization was carried out through a structured survey and social cartography. This project was led by the Science Park for Social Innovation (PCIS) through its Innovaregión Institute.Sustainable development requires a comprehensive approach that takes into account environmental concerns along with economic development. In 1987, the United Nations Brundtland Commission defined sustainability as that which allows the needs of the present to be met without compromising the ability of future generations to meet their own needs. (United Nations, 1987) In Colombia and many other countries they are looking for alternatives to ensure current development without affecting the future, an example of this is the transfer of technology through the Guadua angustifolia Kunth to producers, processors and traders who are actors in rural areas.

Guadua is a fast-growing bamboo species that has great ecological value and is important for the provision of various ecosystem services. One of these services is the protection of the soil thanks to its deep and branched roots that prevent erosion especially in areas of steep slopes (consequently, it helps prevent the loss of nutrients). On the other hand, it also absorbs large amounts of water, facilitating the flow of rivers or streams in dry weather. In addition, it allows pollutants such as nitrogen and phosphorus to be removed, and absorbs large amounts of carbon dioxide from the atmosphere, which helps reduce the effects of climate change. Similarly, in the protection and restoration of areas with erosion or conservation problems, Guadua or bamboo provide an ecosystem service "to provide nutrients through the decomposition of leaf litter, making bamboos a valuable group for the recovery of degraded areas and for the productive restoration of ecosystems, in particular through agroforestry systems" (Ceccon & Gómez-Ruiz, 2019, p.687).

On the other hand, Guadua is an important habitat for a variety of species of fauna and flora, including birds, mammals, insects, and epiphytic plants. The loss of natural habitat is one of the main causes of biodiversity decline, so Guadua is crucial for maintaining biological diversity, therefore, it is a vital resource for environmental sustainability and human well-being. According to Cruz (2016), the Guadua angustifolia Kunth is a non-timber forest grass plant characterized by its economic and environmental potential and because its use contributes to the dynamization and construction of the social fabric. Similarly, because the sustainability of a system would not make sense if the social component is not taken into account.

In the field of tourism, ecotourism, biotourism, rural tourism and other forms of services that can be offered by the inhabitants of rural areas, the Guadua allows them an attractive space for people who want to make a connection with nature. The ecological trails, the walks, the glamping constructions in Guadua, moments of meditation in a guadual, birdwatching areas, respiratory therapy exercises and many activities that are offered to the population that wants to spend a weekend with the family away from technology or who simply want to do a different leisure activity. This allows rural inhabitants to generate income to support their families. To this end, it is necessary to have a vision of a rural entrepreneur individually or in associativity. In addition, the axis of associativity is based on the contribution of communities to food security and sovereignty, most of them supported by the work of women in rural areas.

The project contemplates technology transfer, understood as the process of sharing knowledge, forging a dialogic learning between producer, transformer and merchant with the knowledge that the university professor has. This allowed the discovery of the skills of the participants, to develop new products, processes or services, improve existing ones or solve specific problems. Consequently, a dialogue has been generated between the beneficiaries, the company, the university, research centers and the participation of the government that made the financial resources of the project available. Therefore, the objective of technology transfer makes it possible to convert knowledge and innovations into practical applications with economic, social and environmental benefits. As Vacca and Herrera (2023) mention, the activity related to Guadua-bamboo is becoming more and more relevant in the business world and the contribution to the benefit of the environment is being recognized.

In the process of technology transfer, we worked with two products of Guadua (Guadua angustifolia Kunth) as axes for the training of the 250 people involved. The first is activated carbon, a porous material, with excellent filtration, capable of removing toxic and radioactive substances, and which is used in the chemical, food, and pharmaceutical industries, as well as in water filtration and purification systems (García & Vivar, 2021). This requires temperatures between 700°C to 1100°C and an activation process that can be physical or chemical. Therefore, there is potential for the manufacture of activated carbon for industrial use, mainly in gold mining and in the treatment of waste liquids (Cubillos, 2019). These reasons motivated the beneficiaries to receive the training.

An additional by-product that was worked on together with activated carbon was biochar or biochar which, among other uses, is a good corrector of soil acidity. According to studies carried out by the Research Circle for the Development of the Bamboo Value Chain for Scientific and Technological Development (CIB), the use of biochar in agriculture stands out enormously due to the benefits it has: a) its basic character, it is used as an organic amendment for acidic soils; b) its high porosity, which contributes to improving the soil structure through an increase in water adsorption in the soil; and c) its ability to slowly release nutrients and help improve soil quality. (CIB, 2020). Therefore, "the conversion of common organic waste to biochar provides an option for the treatment of wastes that contribute to environmental sustainability. In addition, the low-cost feedstock and simple preparation process facilitate the practical application of biochar." (Wang & Wang, 2019, p.1019).

The second product was Guadua laminate. This process consists of transforming the Guadua cane (culms) into a more resistant and versatile material, where strips (latillas) of Guadua are used that are subjected to drying, pressing and gluing processes to form panels or sheets. This process makes it possible to obtain large and resistant sheets, which can be used in the construction of ceilings, beams, walls, floors, doors, modular furniture and other architectural and structural elements. The type of glue used must be studied to avoid contamination. Similarly, bamboo (Phyllostachys) is used in other countries. When bamboo is laminated, laminated bamboo is obtained, a product with homogeneous characteristics that can be adapted to modern construction systems, composed of bamboo slats glued and glued, and then pressed (CIB, 2020). Therefore, Guadua-bamboo is a sustainable, attractive and aesthetic material that can add a natural and rustic touch to any construction or interior design project.

1. Materials and methods

For the development of this project, a simple random sampling was carried out, descriptive and statistical inference methods (sampling) were applied to a multistage sample stratified under the law of probabilities. 12 municipalities were selected where the team of field professionals sensitized the population and then 801 people registered. Of these, 54% are men and 46% are women. With this group, conferences, workshops, and knowledge exchange days were held for four months. A socioeconomic characterization was carried out, through a structured survey and social cartography. Four members of the community had the opportunity to participate in a theoretical and practical course on specialized bamboo technology at the prestigious National Agrarian University "La Molina" in Lima (Peru).

The sample of 801 registered students was offered the possibility of participating in the diploma course "Sustainable Transformation of Guadua in Cundinamarca". 250 people were registered to attend their respective sessions in the selected municipalities and received transfer within the framework of the project on Science, Technology and Innovation for Guadua in the Department. The face-to-face sessions in each municipality were attended by groups of 20 to 25 participants, in days of 4 hours per session. The topics were organized, based on the Guadua, on sustainability, project formulation, business, associativity, activated and rolled carbon. The activities were carried out through workshops, field trips, dialogue of knowledge and practices with the machinery that was acquired for them within the framework of the project.

2. Results

The 250 people enrolled in the Diploma on Guadua Technology Transfer develop their professional activity as producers, processors, merchants or interested in learning about the Guadua process. They come from the provinces of Rionegro, Gualivá, Bajo Magdalena and Tequendama, and managed to complete the 240 hours of the Diploma (Figure 1). In their final works, they presented 54 innovative projects, of which 13 were selected to be advised on patent processes and intellectual property issues under the supervision of the Innovaregión Institute and the Secretariat of Science, Technology and Innovation (SCTeI) of the Governorate. Likewise, the remaining projects will have support to strengthen their business ideas and ventures. Therefore, "it is the current actors who can be integrated and be the main managers in projecting this line in an important economic activity for the sustainable development of the territories where this natural resource is produced" (Vacca & Herrera Silva, 2024, p. 6874).

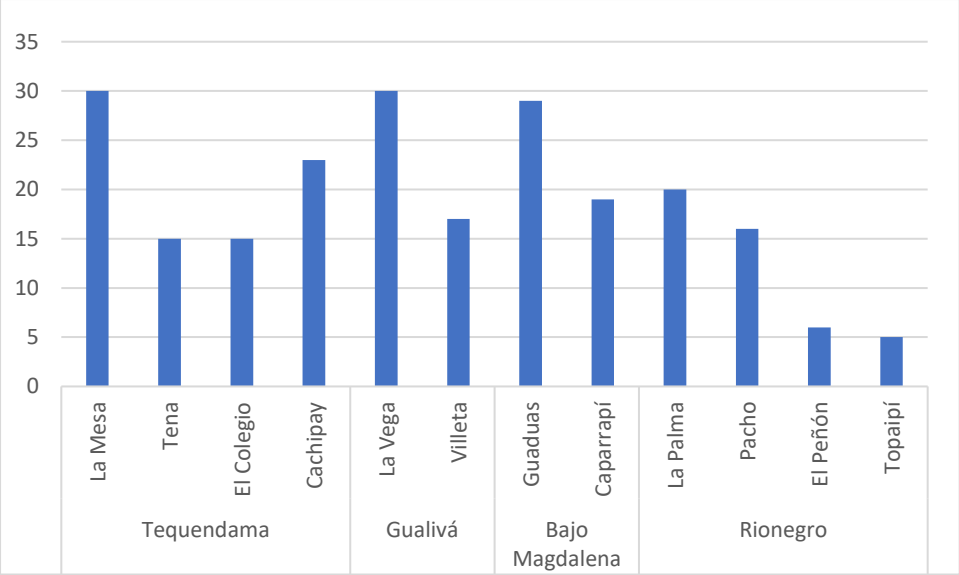

Figure 1 – Graduates of the Diploma in Transformation of *Guadua angustifolia* Kunth. In original Spanish indioma

On the other hand, under the figure of associativity, the project delivered experimental machinery to the community to four "Guaduero Nodes", one per province in order to manage the available machinery. In addition, they can carry out their ventures giving added value and innovation to their Guadua products, encourage the use of appropriate technologies, promote associativity in the communities, as well as transfer the knowledge received in the Diploma to other people. This transfer, through education as a sustainability strategy, has been transferred to the young population to motivate them to find options in rural areas, seeking to promote a new vision of rurality, which allows them to be actors in their own development (García-Marirrodriga, 2011; García-Marirrodriga, 2009; García-Marirrodriga & De los Ríos, 2005). In the "Working With People" planning model, one of its central points mentions that communities are provided "with projects that address the different potentialities and needs of each territory: the social well-being of the population, local economic activities, conservation of natural resources, biodiversity and environmental services projects" (Carzola et al. 2011). In this way, rural-urban migration is reduced and the social fabric is strengthened.

At the research level, it participated in academic events at the national and international level with presentations, a book, a specialized manual, a characterization document and scientific articles were published. These are means to transfer the experience and knowledge of working with rural communities, strengthen the social fabric, contribute to rural inhabitants finding new economic options for their well-being and disseminate a natural resource that is sustainable and that helps mitigate the effect of climate change.

A cross-cutting element in the training process for the participants was focused on environmental sustainability from Guadua and its relationship with the Sustainable Development Goals (SDGs) of the 2030 Agenda. It was based on the knowledge they had about it from their experience, then it was socialized by placing the main elements in common, this generated dialogic learning and the research professor reinforced the concepts explaining the importance of care in the water basins, the realization of silvicultural maintenance, the use of all parts of the Guadua. Likewise, its ecological importance was reflected, since it is a plant that contributes to soil conservation, improves water quality and is a habitat for wildlife. In addition, their cultivation and sustainable use can contribute to the generation of income for local communities and promote the conservation of natural forests. Consequently, they have empowered themselves to make Guadua a sustainable activity.

This allowed the participants to reflect on the importance of Guadua angustifolia Kunth in the face of the SDGs. In the different sessions, elements that make this natural resource an ally for environmental sustainability were worked on and shared. Specifically, we find that it directly contributes to:

SDG 1. End of poverty: Guadua contributes to this objective to the extent that producers, processors and marketers are integrated into the production chain, develop their enterprises in which employment or self-employment is generated and, consequently, the inhabitants improve their economic conditions.

SDG 7. Affordable and clean energy: Bamboo-bamboo according to the International Bamboo and Rattan Organisation - INBAR supports this objective in "three ways: i) helping energy efficiency through the use of waste; ii) improving the energy return of production processes; and iii) improving CO2 absorption". (INBAR, 2018, p.10). It also contributes to circular economy processes.

SDG 8. Decent work and economic growth: Guadua is an important source of employment and income for the local communities that grow and process it. There are several actors involved: from the owner of the farm, administrators, porters, freighters, transporters, warehouses for classification and processing, etc. This also allows the recovery of ancestral knowledge, motivates family work and values the work of rural women, helping to rebuild the social fabric. (Acosta_Leal and Vacca, 2023).

SDG 9. Industry, innovation and infrastructure: Guadua is used in the construction of sustainable and low-cost infrastructures, such as pedestrian bridges, infrastructures on farms, wide roofs for event sites, etc. Therefore, "taking into account the comparison of design resistance between Andean structural woods and Guadua laminates, these are projected as an alternative material of industrial manufacturing engineering, with excellent resistance and environmentally sustainable" (López & Correal, 2009, p.180).

SDG 11. Sustainable cities and communities: Guadua is used in the construction of sustainable, low-cost housing for local communities, which can contribute to reducing poverty and inequality.

SDG 12. Responsible production and consumption: Thanks to its rapid growth, flexibility and resistance, Guadua as a non-timber species is an alternative that is replacing timber species.

SDG 13. Climate action: Guadua-bamboo is a sustainable alternative to building materials that emit large amounts of greenhouse gases. For example, "one hectare of bamboo stores a large amount of carbon, depending on the species and local conditions, but can range from 94 to 392 tons" (INBAR, 2018, p.11). In addition, it provides ecosystem services and contributes to ecotourism services.

SDG 15. Life of terrestrial ecosystems: Guadua is a species native to Latin America and its cultivation and sustainable use contributes to the conservation of terrestrial ecosystems and biodiversity.

In parallel to the SDGs, the Food and Agriculture Organization of the United Nations (FAO) (2014), with the aim of improving the conditions of small agricultural producers and promoting strategies that contribute to the development of their communities, approved the "Principles for Responsible Investment in Agriculture and Food Systems IRA-CFS". For the case that is the object of this research, based on the activities related to the production, transformation and commercialization of Guadua-bamboo in any of its stages, it contributes to these Principles:

Principle 2 that seeks to "Contribute to sustainable and inclusive economic development and poverty eradication" is closely related to SDG 1, as the production of Guadua is promoted, employment or self-employment is generated, it is a source of family income from the ecosystem services offered by Guadua and can be offered on the farm or plot.

Principle 3 "Promote gender equality and women's empowerment" because working Guadua-bamboo allows them to value the work of rural women, who from small enterprises contribute to the family economy, values that female work that presents large gaps compared to urban work (Garza, et al., 2022).

Principle 4 "Enhance youth participation and empowerment" which was part of the work done in the development of the project. As rural youth are involved in processes such as the production, transformation and marketing of bamboo-guadua, they find opportunities for the development of their territories, participate in innovative projects and are motivated to be the protagonists of their own development, consequently rural-urban migration is reduced.

Finally, to Principle 6 "Conserve and sustainably manage natural resources, increase resilience and reduce the risk of catastrophes" because Guadua-bamboo is a strategic ally for soil conservation, the protection of watersheds, in the same way, contributes to the fertilization and renewal of soils, consequently, prevents erosion.

Therefore, Guadua, in addition to being an ally of sustainability, is also an ally of the economy in that it generates employment, allows the marketing of its products and by-products in the national and international market. Consequently, as Cardona (2012) mentions, Guadua, as occurs in other countries with bamboo, could be an important line within the Colombian economy and an example of sustainable management and use of a natural resource.

At the government level, progress has been made thanks to the efforts of people and institutions that for years have insisted on demonstrating the benefits of Guadua and requesting a law that allows

encouraging cultivation in economic lines. To this end, Law 2206 of 2022 was approved, the purpose of which is to "adopt a policy framework that encourages the productive use of Guadua and bamboo in the different sectors of the economy, such as: industry, construction, agribusiness and others, in harmony with environmental sustainability and its ecosystem services in mitigating the effects of climate change". (Law 2206 of 2022, p.1)

3. Conclusions

From a natural resource such as the Guadua angustifolia Kunth, it has been possible to raise awareness of sustainability issues among 250 people in rural areas in Cundinamarca. They, in turn, are going to transfer it to their families and communities. This will be a starting point on the sustainability journey we are all involved in.

The objectives of the Technology Transfer project have been achieved, which allowed the strengthening of the competitiveness of the Guadua production chain through the development and implementation of two technological packages for the generation of value-added products based on activated carbon and rolled in the Department of Cundinamarca.

The by-products of Guadua angustifolia Kunth, such as activated charcoal, allowed the participants to generate innovative ideas. Activated carbon is a product widely used in cosmetics, medicine, household appliances industry and in the future it has a wide market. Likewise, the participants valued learning in the elaboration of biochar or biochar as an element to improve the acidity of agricultural soils.

The laminates of the Guadua angustifolia Kunth are products that in Colombia are just venturing into the market of construction, furniture manufacturing, infrastructure, engineering works, etc. Its national market promises and is expected to reach international markets as the actors in the Guadua production chain recognize the benefits of this natural resource.

At the level of State policies, there is also support. With the approval of Law 2206 of 2022, which allows the spectrum of Guadua angustifolia Kunth to be expanded so that in addition to the silvicultural aspects, it can be considered an agricultural crop and consequently it can be given more use, without neglecting the activities of its sustainable management. Similarly, there are the ICONTEC Technical Standards that give guidance to the different production processes of this natural resource.

The Guadua angustifolia Kunth has been an opportunity to energize actions from the Academy, companies and the State to reach the communities with projects that provide them with scientific knowledge and allow them to return to ancestral knowledge to validate it in research processes. It is an exercise in technology transfer as a social extension of the university to validate and appropriate knowledge, reflect with rural communities on the importance of sustainability and its contribution to the mitigation of climate change.

4. Thanks

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