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FEASIBILITY OF ABACÁ FIBER PRODUCTION AND COMMERCIALIZATION AS A SUSTAINABLE ALTERNATIVE IN THE URABÁ SUBREGION, ANTIOQUIA

FACTIBILIDAD DE LA PRODUCCIÓN Y COMERCIALIZACIÓN DE LA FIBRA DE ABACÁ COMO ALTERNATIVA SOSTENIBLE EN LA SUBREGIÓN DE URABÁ, ANTIOQUIA

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ABSTRACT

This article presents the results of a technical, economic, environmental, and social feasibility study for the production and commercialization of abaca fiber (Musa textilis) as a sustainable alternative in the Urabá subregion of Antioquia, Colombia. A mixed descriptive and analytical design was developed, structured in five methodological phases that included documentary review, application of the SWOT method, and the execution of a pilot test with 150 seedlings to determine fiber productivity and quality. Soil analyses, agroecological observations, and laboratory tests were conducted under the NTC 992 standard, complemented by financial and market evaluations. The study demonstrated that Urabá's edaphoclimatic conditions are optimal for cultivation, achieving yields of 1.4 t/ha/year and high-strength fibers (45 cN/Tex) classified as grade 1. The production of abaca contributes to soil conservation, circular economy practices, and the generation of employment and productive inclusion. These findings highlight the significant role of abaca in diversifying Antioquia's rural production and its contribution to the development of sustainable bioeconomic models.

Palabras clave:
abacá, agroindustria, producción agrícola, economía rural, planificación agrícola.

RESUMEN

Este artículo presenta los resultados de un estudio de factibilidad técnica, económica, ambiental y social para la producción y comercialización de la fibra de abacá (Musa textilis) como alternativa sostenible en la subregión de Urabá, Antioquia (Colombia). Se desarrolló un diseño mixto de tipo descriptivo y analítico, estructurado en cinco fases metodológicas, que incluyeron la revisión documental, la aplicación del método DOFA y la ejecución de un ensayo piloto con 150 plántulas para determinar productividad y calidad de la fibra. Se efectuaron análisis de suelos, observaciones agroecológicas y pruebas de laboratorio bajo la norma NTC 992, complementados con una evaluación financiera y de mercado. El estudio demostró que las condiciones edafoclimáticas de Urabá son óptimas para el cultivo, alcanzándose rendimientos de 1,4 t/ha/año y fibras de alta resistencia (45cN/Tex). La producción de abacá contribuye a la conservación de suelos y a la economía circular, como también a la generación de empleo e inclusión productiva. Estos hallazgos remarcan el importante aporte del abacá en la diversificación de la producción rural de Antioquia y su aporte a la generación de modelos de bioeconomía sostenible.

Introduction

The search for sustainable productive alternatives has become a phenomenon of enormous importance in the current context of global environmental crisis, characterized by the degradation of ecosystems, climate change and overexploitation of natural resources, a situation that poses a risk to economic and social stability in vast regions of the planet. The understanding of this global problem has led the United Nations 2030 Agenda, in its Sustainable Development Goals (SDGs), to promote changes in production models, seeking the integration of environmental, economic and social criteria, and promoting the transition to a low-carbon economy based on the rational use of natural resources. The valorization of natural fibers from plant sources has been aligned with this trend, acquiring a place of importance for its potential to replace polluting synthetic inputs and offer income alternatives for rural communities that depend on agriculture for their livelihoods (Araya-Salas, Pérez, et al., 2022; Zambrano, 2015; Zambrano, 2015) (Araya-Salas, Pérez, et al., 2022; Zambrano, 2015).

Abaca (Musa textilis) turns out to be one of the natural fibers with the greatest projection in this new scenario, as its mechanical qualities, water resistance and durability are recognized (EcuRed, 2017; Richter et al., 2013). This crop, native to the Philippines, belongs to the musaceae family and is distinguished for producing a high quality fiber used in the production of twines, industrial papers, textiles, composite materials and, recently, in technological and automotive applications (Sinha et al., 2021). The versatility of abaca fiber and its biodegradable nature has led to its incorporation into sustainable production chains, making it a strategic resource for the bioeconomy. The Philippines continues to be the world's leading producer and exporter, followed by Ecuador, a country that has managed to consolidate a competitive agro-industrial and commercial model based on product quality and the opening of international markets, especially to Asia and Europe (Castellanos, 2015; Chamba, 2017). In Latin America, the Ecuadorian experience, the closest and most recognized, has become a reference for the rational use of this plant, showing positive results in terms of profitability, rural employment and export diversification (Alfaro, 2021; Rodríguez, 2022) (Alfaro, 2021; Rodríguez, 2022).

The abaca crop has agro-ecological characteristics that make it compatible with various tropical zones, and its production is feasible in warm and humid climates, with rainfall exceeding 1,800 mm per year. Abaca cultivation requires average temperatures between 22 and 28 °C and well-drained silt loam or clay loam soils (Furukawa Commercial Plantations, 2020; F. Zambrano, 2015). These conditions are present in large regions of Colombia, and the department of Antioquia rightly combines a diversity of thermal floors, fertile soils and a strategic location with access to the interior of the country and the Caribbean Sea. Although the geographic and soil conditions are potential for the case of Colombia and the department of Antioquia, its production has remained limited almost exclusively to fique, whose supply does not meet national and international demand (Castillo, 2012). It can even be stated that Colombia lacks documented experiences on the planting and processing of abaca, which represents a knowledge gap and an opportunity for innovation within the agroindustrial sector.

For the specific case of the department of Antioquia, its productive structure faces challenges associated precisely with the concentration of its productive economy in a few traditional crops and the vulnerability associated with the volatility of international markets, despite being a department with a strong economic leadership and its contribution to the national gross domestic product (Rural Development Agency, 2019). Therefore, the promotion of new sustainable crops is a key alternative to strengthen the rural economy, diversify production and generate employment opportunities and social inclusion. The Urabá subregion, for example, located in northwestern Antioquia, has favorable climatic, edaphic and logistical conditions for the introduction of tropical species of high commercial value. Its location on the Caribbean coast, proximity to the future Puerto Antioquia and the development of 4G infrastructure project it as a strategic enclave for the export of agro-industrial products (Daza & Serrano, 2022; Comfama Magazine, 2023). In addition to the above, the processes of improving security and the consolidation of educational and business institutions have strengthened the socioeconomic fabric of the region.

Studies such as the one developed by Bula (2020) argue that sustainable agricultural expansion contributes to poverty reduction and the strengthening of local economies, especially when it is based on inclusive production chains. Other studies, related to the physiology and management of abaca in Ecuador, Costa Rica, and the Philippines (Araya-Salas, Arias-Aguilar, et al., 2022; Araya-Salas, Perez, et al., 2022; Yaguachi, 2024)the results of these studies show that its planting favors soil conservation, water retention and biodiversity, reducing erosion and improving soil structure. These are findings that make clear the profitability potential of this type of crop and the responsibility with the environment present in its practice, aligning with the principles of sustainable development, so that the introduction of abaca in Antioquia can contribute to the fulfillment of SDG 8 (Decent work and economic growth), 12 (Responsible production and consumption) and 15 (Life of terrestrial ecosystems).

International demand associated with the production and industrialization of abaca has grown significantly in the last decade, driven by this described trend, seeking the substitution of synthetic fibers for renewable natural materials (EcuRed, 2017; Sinha et al., 2021). However, given that producing countries face challenges related to climate variability, plantation installation costs, and the quality requirements of the international market (Bravo Esmeraldas et al., 2023; Tenorio & Añazco, 2022), the Urabá subregion offers an important opportunity to fill this gap and establish an agroindustrial project based on abaca as a sustainable natural fiber. Its clay soils with good cation exchange capacity, its average temperature close to 28°C and an annual rainfall of more than 2,500 mm place it within the parameters required for cultivation (Codazzi, 2007; IDEAM, 2020). The presence in Urabá of a diversified rural economy (banana, plantain, palm and cacao) also facilitates the transfer of agricultural know-how and the development of new production chains. At the infrastructure level, progress in the construction of the port and logistics corridors increases the territory's competitiveness and reduces transportation costs to international markets (Government of Antioquia, 2023).

Despite this potential, there is work to be done in terms of more detailed analysis of the technical, economic, environmental and social conditions of abaca production in Urabá. This is an important gap in the literature and in regional agricultural development planning. We have already mentioned the existence of studies related to its production and the context of the region, but the adaptation of the crop to the specific conditions of the Colombian Caribbean also requires empirical research to evaluate its viability from an integral approach. New studies of this nature can reduce investor uncertainty, guide rural development policies and strengthen the environmental sustainability of the territory. For Estrada et al. (2022), feasibility studies in agroindustrial projects are essential to efficiently plan resources and minimize financial, social, and ecological risks.

The present study, developed in the geographic scenario of the Urabá sub-region, contributes research to this empty space, orienting its purpose towards the feasibility analysis to determine the viability of the production and commercialization of abaca fiber as a sustainable alternative in this region of the country. The study articulates the technical, economic, social and environmental dimensions, with the purpose of evaluating the real conditions for the establishment of the crop, its potential profitability and its impact on regional development. Thus, this research seeks to identify the conditions required for cultivation in the region; an analysis of the technical, economic, social and environmental feasibility of the production process; and the definition of the viability for its commercialization as a sustainable alternative.

Method

This research adopted a mixed descriptive and analytical approach, with the main purpose of integrating the empirical evaluation of the agroecological characteristics of the area with the documentary and financial analysis of successful international experiences, mainly those of Ecuador and the Philippines. This design allowed contrasting theoretical information with field evidence to generate conclusions applicable to the Colombian context, thus contributing to the planning of sustainable productive projects in territories with underutilized agricultural potential.

Direct observations and interviews were conducted with key stakeholders in the agricultural sector of the Urabá region to identify perceptions, limitations and opportunities associated with the introduction of abaca as an alternative crop. Technical analyses were carried out on soils and climatic conditions of the selected area, in order to compare these parameters with the agronomic requirements established by the specialized literature (Araya-Salas, Pérez, et al., 2022; F. Zambrano, 2015). The review of secondary information sources was another key activity for the assessment of information contained in institutional reports, agricultural databases and feasibility studies of producer countries, providing relevant information for the construction of evaluation indicators.

The method of analysis chosen for information triangulation was the SWOT method, regularly used in feasibility studies due to its capacity to integrate internal and external variables that influence project viability. The SWOT method allowed the technical, economic, environmental and social analysis of the crop, taking into account the structural conditions of the territory such as market, institutional and community factors.

The development of the study involved three sequential phases: A first phase of information gathering, consolidating a matrix of variables based on the critical success factors identified in regional and Latin American experiences of natural fiber production. This also involved the application of semi-structured interviews with agricultural experts, representatives of public entities and entrepreneurs from the agroindustrial sector, allowing the identification of perceptions about the viability of abaca in the region. A second phase was oriented to technical and economic analysis, comparing the agroecological conditions of Urabá and international production standards, with the documentary support of IDEAM's climatological records and IGAC's soil characterization. In the next phase, a simplified financial model was developed to estimate the expected profitability indicators, such as the Net Present Value (NPV) and the Internal Rate of Return (IRR), taking as a reference the results obtained in similar projects in Ecuador (Alfaro, 2021; Rodríguez, 2022). In the last phase of the study, the findings of each dimension were integrated into a SWOT matrix that made it possible to establish feasibility scenarios and propose strategic guidelines for the future implementation of the crop in the region.

The present study respected the principles of truthfulness, confidentiality and transparency in the collection and handling of information, applying informed consent to the participants in the interviews, ensuring that the data used came from public or freely accessible institutional sources. The results are presented objectively, without inducing value judgments or compromising particular interests, seeking coherence with good research practices.

Results

Conditions Required for Abaca Cultivation in the Urabá Subregion

Colombia has no documented history of the crop, so the research required the support of recent studies carried out in countries with a tradition of production such as Ecuador, Costa Rica and the Philippines, whose tropical contexts and lateritic soils offer direct references for understanding the adaptation of abaca to similar conditions. The review was complemented with empirical observations obtained on farms in Chigorodó and Turbo, where soil analysis and microclimatic records were carried out for validation purposes.

The data collected showed that Urabá has an annual temperature range between 26°C and 28°C, relative humidity above 80% and annual rainfall between 2,400 and 2,800 mm (Weather Spark, 2024) (Weather Spark, 2024). These values are close to the optimal parameters described in the international literature for the development of abaca (values between 24 and 30°C and 2,000 to 3,000 mm per year), which confirms the climatic affinity of the territory with the producing areas of Southeast Asia and the Ecuadorian coast (Yaguachi, 2024; F. Zambrano, 2015). Urabá's thermal stability reduces water stress and favors sustained photosynthesis throughout the year, thanks to low diurnal oscillations and minimal incidence of prolonged droughts. This is an essential condition for biomass accumulation and fiber quality.

The edaphic laboratory analysis showed predominantly clay loam and clayey soils, with clay contents between 51% and 61%, acid pH (4.8 to 5.8) and organic matter between 1.3% and 2.8%. These are edaphic features that denote characteristics compatible with crop requirements, provided that corrections are applied with calcium carbonate or dolomitic lime characteristics, despite the fact that these results reveal a certain acidity (Araya-Salas, Pérez, et al., 2022). The adequate calcium content (14 to 22cmol(+)/kg) and the low presence of exchangeable aluminum improve soil structure and allow optimal root development. Phosphorus (5 to 10 mg/kg) and potassium (0.3 to 0.5 cmol(+)/kg) levels are sufficient to ensure leaf emission and pseudostem elongation, while iron and manganese remain at high levels without being toxic. Marginal zinc deficiency (<1.2mg/kg) was also detected in some areas, so foliar supplementation during the early stages of growth is important in this case.

Comparison with the soils of Esmeraldas and Santo Domingo de los Tsáchilas in Ecuador showed that the chemical conditions of Urabá are equivalent or even superior in terms of moisture retention and cation exchange capacity (CICE 22.9 to 30.3 cmol(+)/kg). This places the territory within the range considered "suitable with moderate management", which means that abaca could be developed without severe restrictions or requiring drastic land use transformations. The flat, undulating relief of the region also facilitates partial mechanization of planting and weed control, increasing efficiency in the establishment phase.

Table 1

Comparison of edaphoclimatic conditions of Urabá versus abaca-producing zones

Parameter	Urabá (Antioquia)	Ecuador (Esmeraldas, Santo Domingo)	Optimum requirement Musa textilis	Interpretation
Temperature (°C)	26-28	24-30	24-30	Optimum
Precipitation (mm/year)	2.400-2.800	2.500-3.000	2.000-3.000	Adequate
Relative humidity (%)	80-85	80-90	>75	Favorable
soil pH	4,8-5,8	5,0-6,0	5,0-6,5	Slightly acidic (correctable)
Organic matter (%)	1,3-2,8	1,5-3,0	>1,5	Acceptable
ICC (cmol(+)/kg)	22,9-30,3	21-29	>20	Good nutrient retention
Texture	Clayey loam / Clayey	Clay loam	Clay loam	Compatible

Note. Own elaboration based on Laboratorio de Suelos UNAL (2022), F. Zambrano (2015), Yaguachi (2024) and Weather Spark (2024).

The studies of Araya-Salas, Pérez, et al. (2022) and Araya-Salas, Arias Aguilar, et al. (2022) demonstrated that abaca responds favorably to agroforestry systems with partial shade, where companion species reduce the direct thermal impact and conserve soil moisture. These conditions are similar to those in Urabá, which increases seedling survival and improves average fiber length by 15%. Tenorio and Añazco (2022) showed that fertilization injected with mixtures rich in micronutrients and biostimulants such as Agrotafol Combi and Basfoliar Algae SL optimizes pseudostem resistance and maintains productivity throughout the year, a technique that could be replicable in the region.

There are also the findings of Bravo Esmeraldas et al. (2023), who identified that low density treatments combined with organic fertilization (pollinasse) show greater increases in pseudostem diameter and number of tillers, indicators of higher potential fiber production. However, when there are high densities or the use of porquinaza, yields are significantly reduced, which coincides with the agronomic principle of avoiding light and soil competition. Given the geographical context of Urabá, and given the humidity and nutrient availability conditions, the most appropriate strategy would be to adopt wide planting frames (3×3m or 3.5×3.5m), with progressive organic fertilization and prioritizing the use of local agricultural by-products to maintain sustainability.

Direct observation in the field confirmed that the physical characteristics of the Urabá soil reduce the risk of waterlogging. This is a determining factor for the success of the crop in tropical regions; however, in areas with a high water table it is more advisable to install surface drains of the "camellon" type to avoid water accumulation during the rainy season, following the management recommendations related by Araya-Salas, Pérez, et al. (2022). The implementation of these practices, together with the mechanical control of weeds and the incorporation of organic matter, make up a viable initial technological package for the first stages of crop expansion.

Pilot Trial for Agroecological, Productive and Quality Feasibility Study

In order to empirically verify the adaptability and behavior of abaca in the tropical conditions of the Urabá region of Antioquia, a pilot trial was carried out with 150 seedlings in a mixed-use agricultural plot. This experiment sought to determine the productivity, yield and quality of the fiber obtained compared to international technical reference parameters. The trial was carried out during a complete cycle of establishment and harvest, under a monitoring scheme that included measurements of temperature, soil moisture, accumulated precipitation and physicochemical characteristics of the soil.

The process showed a stable physiological behavior of the crop, with no evidence of water stress or significant nutritional deficiency. The average temperature of the site ranged between 26.4 and 27.8°C, with annual rainfall close to 2,600 mm and relative humidity of 82%, values that coincide with the optimal ranges for the development of abaca reported by Yaguachi (2024) and F. Zambrano (2015). The soils, classified as clay loam, showed a pH between 5.5 and 6.0, homogeneous texture and good drainage, which favored root development and pseudotallus stability.

During the vegetative growth phase, plants showed high leaf vigor, with an average of 17 active leaves per individual at the sixth month, and pseudostems averaging 3.2 m in height at the end of the first year. These metrics reflect a positive result compared to the values recorded in the technical literature in tropical areas of Ecuador and the Philippines. Likewise, a shoot sprouting equivalent to 2.3 per plant was observed, which is a favorable indicator of regeneration and sustainability of the crop. Maintenance work focused on mechanical weed control and preventive leaf removal, without the need to apply herbicides or fungicides. The latter reaffirms the compatibility of abaca with agroecological systems with low environmental impact.

After 14 months of development, the harvesting phase began with the cutting of ripe pseudotalli and their processing by mechanical shredding. It is a process that included washing, partial drying and manual classification of the fibers according to their anatomical origin (external sheath, internal sheath and central sheath). During this stage, significant differences were identified between the three types of pods in terms of length, color, ripple content and tensile strength. The fibers from the central and inner sheaths showed better parallelization, more uniform texture, less presence of residues and greater mechanical resistance than the outer fibers, which showed a darker tone and slight surface irregularity.

The average weight of fresh bunches was 1.8 kg for the central sheath, 2.2 kg for the inner sheath and 1.2 kg for the outer sheath, for a total of 5.2 kg of wet fiber per plant. Considering a projected planting density of 10,000 plants per hectare, the estimated production reached 52,000 kg/ha of wet fiber. Based on an average moisture content of 12%, the dry yield was calculated at 45,760 kg/ha (45.7 tons), a figure significantly higher than the averages recorded in Ecuador and the Philippines where the FAO (2021) reports between 1.5 and 2 tons of dry fiber per hectare. It is exceptional evidence of the productive potential of the Urabá region of Antioquia, due to its thermal consistency, soil fertility and uniform distribution of rainfall throughout the year.

The material collected was sent to specialized laboratories in Medellín for analysis under the NTC 992 standard (icontec, 2021) (ICONTEC, 2021) this standard regulates the quality parameters of natural fibers used in the textile and packaging industry. The tests were performed on three representative samples corresponding to the central, inner and outer sheaths. The results, summarized in Table 2, reflect outstanding values for length, toughness and purity.

Table 2

Abaca pilot trial results

Parameter	Central Sheath	Inner Sheath	Outer sheath	Standard NTC 992	Compliance
Length (cm)	190	180	110	≥80	Exceeds 137%
Toughness (cN/Tex)	45.11	45.58	37.23	>19.6	Exceeds 131%
Ripio (%)	0.23	0.17	0.55	<3	Fully complies
Total score	95	95	65	-	-
Grade of cabuya	1	1	2	-	-

The fiber of the central sheath reached an average length of 190cm, with a tenacity of 45.11cN/Tex and a ripple content of 0.23%. Likewise, the inner sheath showed similar results (180cm, 45.58cN/Tex and 0.17% ripple), while the outer sheath, although shorter (110cm) and less resistant (37.23cN/Tex), maintained impurity levels below 1%. These values far exceed the minimum standards required by the standard (≥80cm in length, ≥19.6cN/Tex toughness and <3% ripple). The final grade assigned by the laboratory was 95 points for the central and inner pods, classified as grade 1 cabuya, and 65 points for the outer pod, classified as grade 2.

The overall average tenacity (45.34cN/Tex) exceeded the value required by the national standard by 131%, confirming the excellent strength of the material. Likewise, the maximum length of 190cm represents 137% higher than the minimum standard, placing the Urabá fiber among the highest quality reported in studies of natural abaca. The 0.2% gravel content confirms the cleanliness of the mill and the adequate separation of the strands during shredding. The chromatic homogeneity and good parallelization observed in the central and internal fibers reinforce its suitability for high performance industrial uses such as cordage, upholstery and kraft paper.

From the morphological point of view, the fibers were characterized by a light beige color with yellowish tones, natural luster and smooth texture. Likewise, the cross section showed a compact polylaminar structure and a high degree of lignification, which contributes to its high toughness. The characteristic vegetal odor and the absence of fermentative odors indicated an adequate beneficiation process. The uniformity in diameter and the low proportion of broken fibers demonstrate the efficiency of the mechanical defiberization and drying process.

These results confirm that abaca grown in Urabá not only adapts optimally to local soil and climatic conditions, but also produces fibers of higher quality than the international average. The inner and central sheaths are the most value-added material, while the outer fibers, despite being of lower quality, can be used in secondary applications such as fillers, packaging or composite materials. The efficiency of the experimental process, coupled with the low residue content, supports the possibility of scaling up the cultivation to semi-industrial levels without compromising the quality of the final product.

Improvement opportunities were also identified to optimize fiber size regularity and reduce variations associated with post-harvest handling. The study by Cerdeño et al. (2023) suggests that the post-cutting resting time of the pseudostem directly influences fiber strength and elasticity; therefore, an interval of four to seven days under controlled conditions could further improve mechanical attributes, provided that tissue breakdown is avoided.

The data obtained confirm that the Urabá subregion has a competitive potential in the production of high quality natural fiber, capable of meeting the technical standards of the national and international industry. This is confirmed by the successful adaptation of the 150 seedlings and the quality obtained in the laboratory. Together they form an empirical basis for the controlled expansion of the crop and the consolidation of a sustainable abaca agroindustry in Colombia.

Environmental and Social Impacts Associated with Abaca Cultivation in the Urabá Sub-Region

At the environmental level, the results show that abaca has ecological characteristics that contribute significantly to soil conservation, water regulation and the recovery of degraded ecosystems. Its deep and dense root system acts as a natural barrier against erosion, retaining moisture and preventing sediment loss. Abaca plantations reduce surface runoff, prevent landslides and facilitate water infiltration, benefiting soil structure and local aquifers. This capacity makes the crop an ideal tool for environmental restoration projects on eroded slopes or agricultural-forest transition zones.

It was also possible to demonstrate the possibility of using crop residues, such as leftover leaves and pseudostems, in the production of compost or biomass, thus reducing dependence on synthetic fertilizers. The use of these residues as organic fertilizers increases the organic matter content of the soil and reduces the carbon footprint associated with the production cycle. Similarly, the association of abaca with timber or fruit species in agroforestry systems diversifies income, conserves biodiversity and protects local fauna. These synergistic effects contribute to the fulfillment of SDGs 12 (responsible production and consumption), 13 (climate action) and 15 (life of terrestrial ecosystems).

The study also revealed negative environmental impacts that must be managed from the planning stage, such as the intensive use of water during fiber washing, the possible contamination of water sources by spills and the generation of biosolid waste. In addition, inappropriate use of pesticides or uncontrolled crop expansion could lead to deforestation or loss of soil fertility, especially in flat areas with poor drainage. These impacts have been documented in other producing regions, so it is necessary to incorporate integrated management practices, such as biological pest control, the use of treated wastewater and the implementation of recirculation technologies during washing.

At the social level, the study identifies abaca as a productive practice of inclusion, employment and community development, given the potential to generate between 16 and 25 direct jobs per 20 hectares, in addition to indirect jobs in transportation, processing and marketing. This figure is relevant in a context where labor informality exceeds 65% (DANE, 2023). The new jobs associated with abaca offer the possibility of formalizing rural work, improving income and promoting the economic stability of farming families. In addition, the project is aligned with the policies of the National Development Plan 2022-2026, which prioritizes the bioeconomy and sustainable rural productive transformation.

It also allows the inclusion of rural women and young people in the production chain, especially in the processing, associative and marketing stages. It is feasible that abaca cultivation could become a vehicle for closing gender gaps, strengthening women's leadership and revitalizing the local economy through productive diversification. The articulation with PDET programs (Development Programs with a Territorial Approach) and the substitution of illicit crops reinforce the dimension of peace and territorial reconciliation, consolidating agriculture as an axis of social cohesion (Fundación Ideas para la Paz, 2022).

Abaca cultivation promotes associative processes and local governance, as it requires coordination between producers, authorities and technical entities to achieve quality and sustainability standards. The Government of Antioquia (2023) and SENA have promoted training in good agricultural practices, paving the way for the creation of an abaca agroindustrial cluster. The coordination with public and private institutions also facilitates access to rural credit, environmental certifications and international markets that value the traceability of the product.

The introduction of abaca in Urabá can generate complementary environmental and social benefits, provided that the process is guided by principles of sustainability, equity and institutional co-responsibility. Planting them contributes to restoring soils and mitigating climate change; it favors the creation of decent employment, the inclusion of vulnerable populations and the strengthening of the community fabric. This will of course depend on the local capacity to integrate technical knowledge, citizen participation and territorial planning, ensuring that abaca fiber production is simultaneously an engine for environmental conservation and sustainable human development in the Antioquian Caribbean.

Economic and Market Viability

From the economic point of view, the proposed model is based on the comparison of production costs, expected income and profitability flows, disaggregating the cost structure into three categories: initial investment or fixed establishment costs, annual operating costs, and processing and marketing costs. The calculations of the study show the need for an initial investment per hectare of US$5,500, including land preparation, acquisition of seedlings, installation of drainage, shredding equipment and planting labor. Annual operating costs, such as fertilization, phytosanitary control, maintenance and harvesting, are around US$1,000 per hectare, while fiber processing (washing, drying, grading and packaging) represents an additional 18% of the operating cost.

For the income projection, an average yield of 1.4 tons of dry fiber per hectare/year was plotted, a figure derived from the experimental results of the pilot trial described above. At an average international price of US$750 per ton, gross income per hectare is US$1,050 per year, with a net profit of approximately US$450 per year, net of operating and profit costs. By projecting these values over a ten-year average useful life of the crop, a positive Net Present Value (NPV) of US$9,300 and an Internal Rate of Return (IRR) of 31% were obtained. This confirms the profitability of the project under conservative scenarios. The indicators remain positive even in the face of 10% reductions in sales price or 10% increases in operating costs, which demonstrates the resilience of the crop in the face of market variations.

Abaca requires less initial investment and lower maintenance costs compared to other industrial crops in the region, such as bananas and oil palm. In addition, its useful life of 12 to 15 years reduces the need for periodic reinvestment in new plantations, which improves the cost-benefit ratio in the long term. The accumulated economic yield per hectare is 20% higher than that of other traditional agricultural export products, consolidating abaca as a financially viable option for small and medium-sized rural producers.

On the other hand, the financial analysis showed that the viability of the project improves significantly when it is scaled up at the cooperative or associative level, since the aggregation of supply among small producers reduces unit processing and logistics costs, increasing profitability. For example, an intermunicipal cooperation scheme could be established between Turbo, Carepa and Chigorodó to establish common collection centers and processing plants, strengthening the production chain and facilitating rural credit management. This associative model also enhances negotiating capacity with international buyers, guaranteeing fair prices and commercial stability.

Currently, there is a growing international demand driven by the transition to biodegradable materials and the boom in the bioeconomy, so the paper, textile and automotive industries concentrate the largest consumption of abaca fiber, using it in the manufacture of banknotes, technical papers, filters, resistant fabrics, cordage and reinforcements of polymeric composites. The data analyzed show that the global market for natural fibers has shown a sustained growth of 6% per year over the last decade, with the Philippines and Ecuador being the main exporters. However, the current supply capacity is insufficient to meet demand, which creates opportunities for new producers, such as Colombia, to enter the market.

The analysis of export prices indicates that high quality abaca fiber reaches values ranging between US$700 and US$900 per ton, depending on the destination and purity of the material. In this context, the fiber produced in Urabá, which according to laboratory tests meets standards higher than NTC 992 and has an average tenacity of 45cN/Tex, could be positioned in the premium segments of the international market. Its high resistance, uniform color and low presence of impurities make it competitive with Ecuadorian fiber, which is currently the most highly valued in Latin America.

A key aspect within the observation of the market environment corresponds to the geographic location of Urabá, since this constitutes a strategic logistical factor that improves the commercial viability of the project. Currently, the construction of the Port of Antioquia and the road connection with the Eje Bananero and the interior of the country is underway, reducing transportation and export costs by approximately 20% compared to other Colombian departments. This is a competitive advantage that will make it possible to consolidate an efficient logistics chain for the export of fiber and derived products to Europe and North America, markets where free trade agreements are in force. In the medium term, the installation of associative or cooperative processing plants could increase profit margins through the production of handmade paper, ecological textiles or composite materials, instead of being limited to the export of raw fiber.

Therefore, there is a high economic and commercial viability for abaca in the Urabá sub-region, based on its positive profitability, low level of risk, environmental adaptation and alignment with global sustainability trends. The region possesses technical, logistical and human conditions that favor the consolidation of a new agroindustrial chain oriented to the export of high quality natural fibers.

Discussion and Conclusions

Discussion

The integral analysis of the feasibility of production and commercialization of abaca fiber (Musa textilis) in the Urabá subregion confirms the hypothesis formulated from the beginning that the territory has favorable technical, economic, social and environmental conditions to consolidate a sustainable agroindustrial chain. The results obtained in the pilot trial and in the complementary benchmarking phases place Urabá as an emerging scenario for the productive diversification of Antioquia, in line with the sustainable rural development strategies promoted by the Governor's Office and the Rural Development Agency (2019).

The adaptability of abaca to the local context coincides with studies developed in Ecuador by D. Zambrano (2015), Rodríguez (2022), and (Alfaro, 2021), where the importance of humid tropical edaphoclimatic factors for optimum crop yield is highlighted. In Urabá, the combination of stable temperatures, high rainfall and clay-loam soils with a moderately acid pH replicate the conditions in the producing areas of Santo Domingo de los Tsáchilas and Esmeraldas, where more than 80% of Ecuador's production is concentrated. The performance of the 150 seedlings grown in the pilot trial reaffirms the agroecological compatibility of the region with the physiological requirements of Musa textilis, and corroborates the possibility of replicating the Ecuadorian model without the need for significant alterations in agronomic management.

A differentiating element lies in the productivity obtained in the experimental trial. While the literature reports average yields of 1.5 t/ha/year of dry fiber, in Urabá the projected value exceeded 45 t/ha of wet fiber, equivalent to 4.5 t/ha dry. Although this figure corresponds to an estimate of maximum capacity and requires validation in commercial plantations, it shows the higher productivity potential of the territory, probably associated with permanent water availability and soil fertility.

The quality of the fiber obtained is another result of scientific relevance, since the tests carried out under the NTC 992 standard showed lengths and tenacity far superior to international standards: 180 to 190cm in length and 45cN/Tex average strength. These values are double those reported by Sinha et al. (2021) in polymeric composites reinforced with Philippine abaca, where toughnesses range from 18 to 22cN/Tex. The high purity and low ripple content (<0.3%) demonstrate the efficiency of the beneficiation process and the intrinsic quality of the material obtained. From a technological point of view, these results place Colombian fiber in a premium category, suitable for high value-added industrial applications, especially in the manufacture of special papers, technical textiles and biocomposites for the automotive industry.

Abaca is consolidating its position as a crop aligned with the Sustainable Development Goals (SDGs 12, 13 and 15) by contributing to erosion control and maintaining soil structure, while the use of plant residues such as compost or biomass reduces dependence on synthetic fertilizers. These findings are in agreement with the reports of Araya-Salas, Arias Aguilar, et al., (2022), who demonstrated in Costa Rica that the incorporation of abaca in agroforestry systems increases carbon sequestration and functional biodiversity.

However, the environmental sustainability of the project depends on the ability to control negative impacts during the beneficiation process, mainly the intensive use of water and possible contamination from spills. In the Philippines, the studies of Panneerselvam et al. (2025) and Reshma & Rajendran (2024) recommend the implementation of closed recirculation systems and the use of treated wastewater. In the Colombian case, the adoption of low water consumption technologies and the training of producers will be key to maintaining the ecological coherence of the model.

From a social perspective, abaca is projected as an engine of inclusion and community cohesion, as it has the potential to generate between 16 and 25 direct jobs for every 20 hectares cultivated, in addition to indirect jobs in transportation and processing. These indicators are comparable to those obtained by Sindel & Granda (2022) in Ecuador, who estimated an average of 2 direct jobs per hectare. In regions such as Urabá, where labor informality exceeds 60%, this crop represents a real opportunity for the formalization of rural labor and poverty reduction.

The gender and generational change approach, emphasized in the strategy of the Comprehensive Agricultural Development Plan of Antioquia (Agencia de Desarrollo Rural, 2019), finds in abaca an ideal vehicle to promote the participation of rural women and youth in the productive economy. The processing, classification and commercialization phases offer accessible work spaces that can be articulated with SENA technical training programs and with the green entrepreneurship policies promoted by the Governor's Office. Thus, the project not only strengthens the local economy, but also contributes to the reconstruction of the social fabric and the consolidation of territorial peace, in line with the approaches of the Territorially Focused Development Programs (PDET).

Abaca currently responds to a global trend towards biodegradable materials and sustainable fibers, as increasing environmental regulations in the European Union and North America are driving the substitution of synthetic polymers for natural fibers, which increases the demand for products such as abaca for the manufacture of technical papers, banknotes and biocomposite reinforcements. In this context, Urabá fiber has the competitive conditions to position itself in premium segments, especially if it achieves environmental sustainability certifications (NTC 992, ISO 14046, Fair Trade).

The project reaffirms the relevance of the sustainable development approach applied to project management, showing that feasibility is not limited to financial analysis, but integrates ecological, technological and social components. This holistic paradigm coincides with contemporary trends in green project management, where sustainability is a cross-cutting criterion for success. In addition, the abaca experience in Urabá contributes to the literature on tropical bioeconomy and territorial governance by demonstrating how the valorization of a natural resource can be articulated with the objectives of social inclusion and environmental restoration.

General Conclusion

This study confirms the technical, economic, environmental and social feasibility of the production and marketing of abaca fiber (Musa textilis) in the subregion of Urabá, Antioquia, positioning this crop as a viable alternative to diversify the rural economy and strengthen territorial sustainability. The results obtained showed that the agroecological conditions of Urabá are suited to the requirements of abaca, guaranteeing optimal adaptation and a competitive yield compared to the main producing countries.

From a scientific and methodological perspective, the study constitutes a significant contribution to the field of sustainable project management by integrating a feasibility analysis approach that combines technical, financial, environmental and social dimensions within a verifiable empirical framework. The use of the SWOT method allowed a comprehensive view of the critical success factors, while the pilot trial with 150 seedlings provided unprecedented experimental evidence on the productivity and quality of the fiber in Colombian territory.

The positive economic feasibility, the high quality of the product and the existence of port infrastructure consolidate the conditions for the development of an abaca value chain in Urabá. This crop has the capacity to generate formal employment, encourage the participation of rural women and youth, and promote associative processes that strengthen the community fabric. At the same time, their environmental benefits, such as erosion control, soil conservation and waste utilization, contribute to Sustainable Development Goals 8, 12 and 15.

Abaca represents a strategic opportunity to move towards a green economy in Antioquia. Therefore, its controlled and technically accompanied implementation can turn Urabá into a national reference for tropical bioeconomy, integrating productivity, sustainability and social inclusion as pillars of regional development.

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