Blockchain-based decarbonization in Cereté: Prototype for local ecosystem conservation

Descarbonización con Blockchain en Cereté: prototipo para conservar ecosistemas locales

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Abstract: The article presents the global problem of pollution and climate change through sustainable solutions, highlighting the growth of carbon markets as tools to reduce emissions and improve air quality. The carbon credit initiative is presented as a strategy to counteract air pollution and promote sustainable practices, the proposal is developed in Cereté, Colombia; the proposal explores the feasibility of a business model based on carbon credits, integrating emerging technologies such as blockchain. A mixed research approach is adopted and phases are proposed for the development of the project, including awareness raising, requirements analysis, competition and theoretical models of intervention. Proposals include actions to conserve biodiversity, environmental and technological education, equitable access to business opportunities, social benefits, fair pricing for carbon sequestration, platform security and

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transparency, and quality auditing, with the objective of protecting the municipality's strategic ecosystems.

Keywords: Pollution, carbon credits, blockchain, sustainability, Cereté, carbon footprint, carbon credits.

Resumen*:* El artículo presenta la problemática a nivel global de contaminación y el cambio climático mediante soluciones sostenibles, destacando el crecimiento de los mercados de carbono como herramientas para reducir emisiones y mejorar la calidad del aire. Se presenta la iniciativa de bonos o créditos de carbono como una estrategia para contrarrestar la contaminación atmosférica y fomentar prácticas sostenibles, la propuesta se desarrolla en Cereté, Colombia; la propuesta explora la viabilidad de un modelo de negocio basado en créditos de carbono, integrando tecnologías emergentes como blockchain. Se adopta un enfoque mixto de investigación y se proponen fases para el desarrollo del proyecto, incluyendo la concientización, análisis de requerimientos, competencia y modelos teóricos de intervención. Las propuestas incluyen acciones para conservar la biodiversidad, educación ambiental y tecnológica, acceso equitativo a oportunidades de negocio, beneficios sociales, fijación de precios justos por la captación de carbono, seguridad y transparencia de la plataforma, y auditoría de calidad, con el objetivo de proteger los ecosistemas estratégicos del municipio.

Palabras clave: Contaminación, bonos de carbono, blockchain, sostenibilidad, Cereté, huella de carbono.

1. Introduction

Currently, global pollution, carbon dioxide CO2 emissions and climate change are topics of global discussion and concern, stimulating the search for sustainable and effective solutions. Specialized literature, as well as reports from international institutions, highlight the urgency of

facing these environmental challenges, underlining the importance of the Sustainable Development Goals (SDGs) to reduce the impact of human activities on the climate and the natural environment [1].

Globally, carbon markets have experienced a fundamental increase, becoming key tools to encourage investment in projects that contribute to reducing emissions and improving air quality [2]. Evidence of this progress is reflected in the market value of carbon credits, which reached almost $2 billion in 2021, showing a remarkable expansion from less than $200 million five years ago [3]. The carbon credit initiative emerges as an innovative strategy to counterbalance air pollution generated by companies and factories, while incentivizing more sustainable practices [4].

In Latin America, World Bank-supported projects and similar programs have demonstrated how carbon credits can serve as economic incentives for the development of sustainable agricultural and livestock practices, highlighting the applicability of these mechanisms in different regional contexts [5].

In Colombia, the implementation of carbon credits has begun to gain traction, which proposes considerable potential for the expansion of these models to other regions of the country, including municipalities such as Cereté in Córdoba [6].

The use of blockchain technology emerges as a promising solution to ensure transparency and traceability of carbon credit transactions, a critical aspect for the reliability and efficiency of the proposed system. The adoption of this technology could mean a step forward in the implementation of more sustainable and ethical practices in the carbon market [7].

This study aims to explore the feasibility of implementing a business model based on carbon credits in Cereté, Córdoba, Colombia; seeking to promote sustainable practices in the community and offer new economic opportunities [8].

A carbon credit model for the region is proposed, considering international and regional experiences, as well as the integration of emerging technologies such as blockchain. This approach not only aims to offer a local solution to a global problem, but also to establish a replicable model that can be adapted and applied in other regions of the country and the world.

2. Methodology and Experimentation

2.1. Methodological Design

The methodological approach of the research adopts a mixed approach, merging aspects of quantitative and qualitative research [9]. This combination enables a deeper appreciation of the problem, as well as a more comprehensive solution proposal [10].

2.2. Population and Sample

The study population, located in Cereté, Córdoba, reported a total of 114,106 inhabitants, composed of 58,287 women (51.1%) and 55,819 men (48.9%) [11]. For the research, a sample of 383 people was selected using a non-probabilistic purposive sampling method known as snowball, characterized by demographic and socioeconomic information [12].

2.2.1. *Geographic and demographic context of the study area*

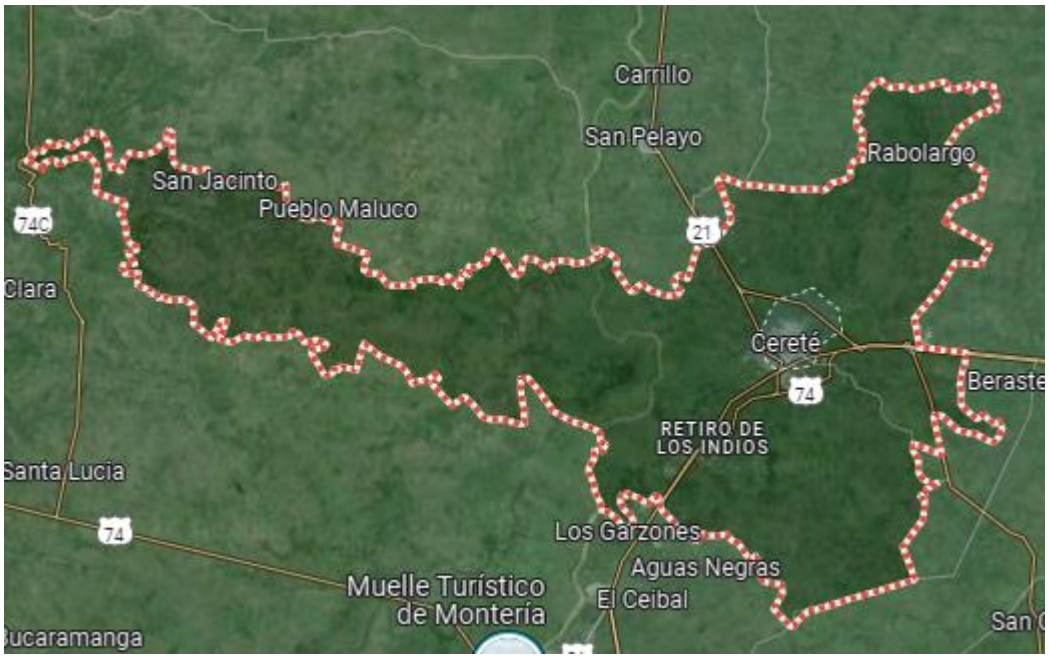

Figure 1. Satellite map of Cereté, Córdoba.

Source: Google Maps.

The municipality of Cereté is located in the hydrographic basin of the Sinú River, in the region known as Medio Sinú, and stands out as an important road interconnection center on the Troncal de Occidente, 18 km from Montería, capital of the Department of Córdoba [13]. According to Figure 1, Cereté is bordered to the north by the municipalities of San Pelayo and Chimá, to the east by Ciénaga de Oro, to the west by Montería and to the south by San Carlos and Montería.

Politically, the municipality is composed of nine townships and has fifty-six villages in the rural area and fifty-two neighborhoods in the urban area. Its geographic center is located at 75°42' west longitude and 8°50' north latitude. The total area of the municipality is 6,293 km², with an urban area of 278.8 km^2 [13].

The Sinú River flows through Cereté in the Medio Sinú subregion, which makes the soils fertile and favors the development of agribusiness.

2.2.2. *Economic Context*

Since the mid-20th century, agriculture has been the economic mainstay of Cereté. However, this activity, although it generates linkages with other sectors, has not been sufficient to pull the municipality out of its precarious economic situation. Cereté faces difficulties in terms of employment generation, access to basic services, and infrastructure development.

In terms of education, Cereté has a high coverage and internal efficiency of the system, but the results in terms of quality are deficient. The lack of resources and limited infrastructure affect the quality of education offered in the municipality, which in turn impacts the development opportunities of its inhabitants [14].

2.3. Phases

The following three phases were carried out for the development of this research:

2.3.1. *Phase 1 or Awareness and Initial Co-Creation*

The purpose of this phase is to recognize the needs, problems and opportunities of a potential market, to which a solution is offered through a differentiated value proposition.

In order to promote decarbonization in the agricultural sector of the municipality of Cereté, Córdoba, Colombia, four proposals were initially generated:

Carbon Credit Marketplace	**Green Innovation Center**	**Education and Awareness**	**Green Marketing and Networking**
A blockchain-based digital Marketplace was proposed to facilitate the purchase and sale of carbon credits, as well as supply chain verification services to certify sustainable food production.	It was proposed to establish a research and development center dedicated to sustainable technologies, with the objective of fostering collaboration between local companies and the implementation of eco-friendly practices.	It was suggested to develop educational programs on environmental issues, using carbon credits as an incentive for community participation in decarbonization initiatives.	It was proposed to carry out marketing campaigns focused on highlighting the benefits of decarbonization, as well as to establish a collaboration network among different actors, such as producers, consumers, companies and governmental entitie s.

Table 1. Initial Awareness and Co-Creation Proposals**.**

Source: Own elaboration.

2.3.2. *Phase 2 or Requirements and Competition Analysis*

This phase focuses on gathering and analyzing customer requirements, as well as assessing the competition in the relevant market. During this phase, the following activities are carried out: Identification of customer requirements, Quality Function Deployment (QFD) and Analysis of competing companies.

In the framework of the decarbonization project in the community of Cereté, the activities mentioned above were implemented for the evaluation of the feasibility in the commercial application of the decarbonization prototype with blockchain technologies [15].

✓ A functional analysis was performed where customer requirements were identified, such as:

- The decarbonization platform must be easy to use and accessible to the population and companies involved.
- Training must be practical and relevant to the needs of the populations.
- Technical assistance must be personalized and timely.

These requirements translate into functionalities that the decarbonization platform must have such as intuitive design and user-friendly interface, customized training, focus on sustainable practices, continuous accompaniment, monitoring and evaluation.

✓ Quality Function Deployment (QFD) was conducted as an integral part of the study. This systematic procedure started with the collection of customer requirements, through strategic design, followed by ranking and prioritization. Since the decarbonization prototype is not conceived as a tangible product, but as a service, qualitative variables were selected, considering their relevance to the prototype objectives. QFD matrices were used to establish relationships between these requirements and the service characteristics, assigning values that reflect the

relative importance of each relationship. This information guides the design and development of the initiative, ensuring the effective and efficient satisfaction of the client's needs and expectations.

Considering the inherent autonomy of the study, the following actions were executed to establish the study variables:

Quality Demanded: The variables included in the "Quality Demanded" section reflect the needs and expectations of customers with respect to the service offered.

- Customer opinions and comments were tracked on online platforms, such as websites, social networks and specialized forums.
- A thorough analysis of the features and advantages provided by competing companies was carried out.

Quality Characteristics: The variables selected as "Quality Characteristics" represent the attributes of the service that must be developed to satisfy the needs and expectations of the clients.

- The relationship between customer needs and service characteristics was established.
- The technical and economic feasibility of the features was evaluated.
- The differentiation capacity vis-à-vis the competition offered by these features was examined.

2.3.3. *Phase 3 or Theoretical intervention models*

Phase 3 or final phase focuses on the development and design of conceptual and methodological approaches to address the needs identified in the previous phase.

During this phase, the following activities were carried out:

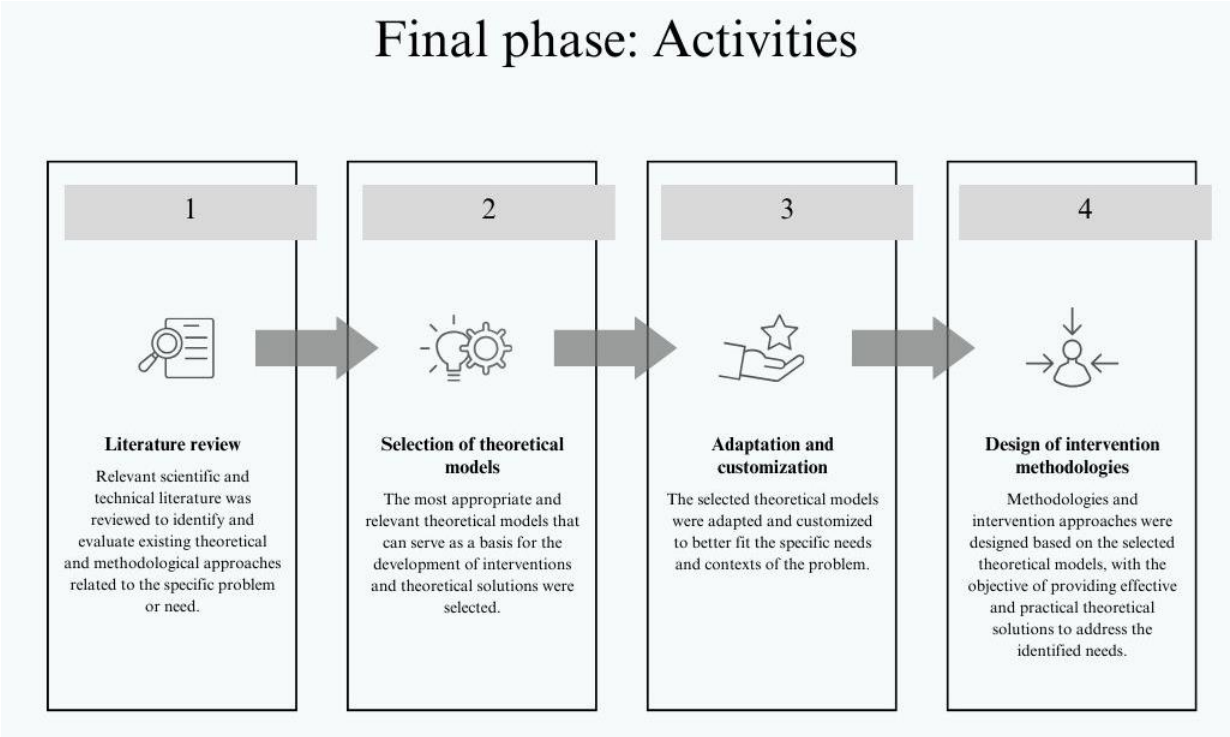

Figure 2. Final phase: Activities.

Source: Own elaboration.

Following the sequence of activities presented in Figure 2 and considering the criteria established in phase 2, intervention methodologies were designed to analyze each variable identified through Quality Function Deployment (QFD). This process was oriented towards the preparation of its future implementation in the generation of theoretical solutions.

In the context of the study, which focuses on a development plan aimed at a decarbonization prototype based on carbon credit trading, considering the socioeconomic objective of establishing a business model and improving living conditions in the municipality of Cereté, the intervention methodologies devised represent concrete proposals that materialize the ongoing research.

3. Proposals

Considering phase 2 or Requirements and Competition Analysis, variables such as environmental and technological education, equitable access to business opportunities, social benefits, fair

pricing for carbon capture, platform security and transparency, and quality auditing were evaluated (See figure 3).

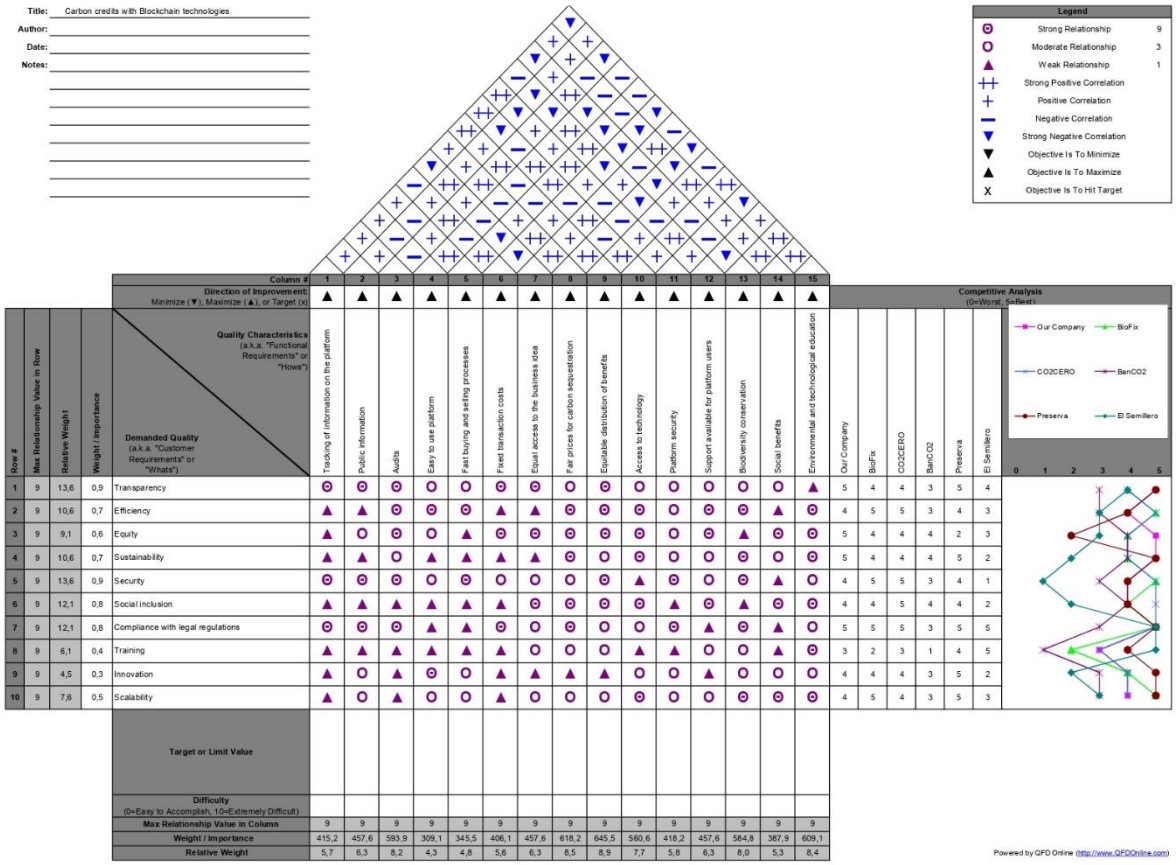

Figure 3. Quality Function Deployment House.

Source: Own elaboration.

In line with the final phase of the process, intervention methodologies have been used as a reference to address these critical aspects, proposing theoretical solutions that lay the groundwork for the future implementation and commercial validation of the decarbonization prototype, supported by blockchain technologies, whose objective is to protect the municipality's strategic ecosystems.

✓ Theoretical solutions

Biodiversity conservation

The IAP and Awake methodologies will be used, where the IAP Methodology involves research, action and participation to understand and transform social reality and Awake focuses on environmental protection in Colombia, collaborating with local communities in biodiversity monitoring and conservation training; to guide the approach to the identified critical points [16], [17].

Initially, a plan of activities and strategies will be designed following the sequence outlined below:

- Group meeting: This inaugural phase is of fundamental importance as it allows participants to freely express their needs and expectations regarding the future project.
- Needs Identification and Self-diagnosis: A detailed document is prepared describing the environmental needs of the community.
- Project Area Exploration: Information is provided to the community about the green areas where the project will be carried out.

Subsequently, the following actions will be applied using the Awake methodology:

- Monitoring programs: Programs adapted to the characteristics of the municipality are established, including the use of technologies such as camera traps and acoustic sensors to collect data on local fauna and flora [18].
- Development of Conservation Projects: Specific projects are identified and developed that address the priority needs of the municipality, such as the restoration of degraded ecosystems and the protection of key natural areas [17].

- Monitoring and Evaluation: The activities and projects implemented are followed up, evaluating their impact on the community and the environment to adjust strategies and guarantee conservation and sustainable development objectives.

Environmental and technological education

To address the educational needs of the population, a four-phase action plan will be implemented to establish a community education center that addresses environmental and technological aspects:

- Diagnosis: A participatory analysis is conducted through surveys, interviews and community meetings to understand current perceptions about the environment and technology, identifying knowledge gaps and relevant demographic characteristics.

- Creation: Leaders and coordinators are designated in collaboration with the community to manage the project and establish relationships with other entities.

- Operation: Educational activities such as courses and workshops are carried out to train people in environmental care and technological adaptation, in addition to providing a variety of educational material.

- Regulation: Continuous self-evaluation is carried out to improve the center's operation and assess its impact on the community.

Equal access to the business idea

Continuing with the previous action plan, it will be planned to provide people with the necessary tools and conditions to access the materialization of their business ideas. This process will be divided into two stages:

- Access to Tools: Partnerships are established with government and non-profit organizations to overcome connectivity challenges by providing access to shared workspaces, computer equipment and digital tools [2].

- Access Conditions: A selection process is structured considering criteria such as technical and financial feasibility, environmental impact and alignment with sustainable development objectives [2], using a multi-criteria matrix. The evaluation matrix considers the coherence, suitability, environmental contribution and articulation of capacities in the project.

Social benefits

To address the critical points identified, strategies will be proposed such as:

- To address the critical points identified, strategies will be proposed such as:

Creation of a Seed Capital Fund: Eligibility criteria, amount and structure of financing are defined, a selection committee is formed and a transparent application and evaluation process is developed.

- Support for Microentrepreneurs and Farmers: A support network is established that includes services such as business advice, technical training and market access, fostering collaboration and linking microentrepreneurs with training institutions [19], [20].

- Promotion of Public Procurement of Products and Services from Microenterprises: Inclusive public procurement policies are implemented, a catalog of microenterprise suppliers is created, and public officials are trained in inclusive public procurement [19], [20].

- Monitoring and Evaluation: Monitoring indicators are established and periodic evaluations of the program are carried out, promoting transparency and accountability at all stages of the process.

Fair prices for carbon sequestration

To ensure fair compensation for carbon sequestration, a two-phase approach will be proposed:

➢Price Adjustment per Ton: A section is implemented on the website that adjusts prices according to the location of the buyer, considering the cost of carbon capture technologies, environmental and social benefits of the project, and international carbon credit market conditions [5].

➢ Forest Topographic Survey: A team is appointed to conduct a forest topographic survey in the target region to determine carbon emissions per square meter of study area for accurate and fair compensation.

Platform security and transparency

➢ Payment Methods, Trust and Research: The choice of payment system is based on trust and ease of use. Advanced solutions are adopted, such as artificial intelligence systems for real-time analysis of suspicious transactions and detection of fraud patterns. Data mining techniques are implemented to examine large volumes of information and prevent fraudulent activities, by identifying anomalies and developing predictive risk models [21].

➢ Fraud Prevention: A multi-layered approach to fraud prevention is designed. This includes user authentication measures using biometric identity verification, one-time authentication codes, and behavioral analysis. Advanced data encryption techniques are applied to protect sensitive information and regular security audits are conducted to identify potential vulnerabilities and continuously improve the platform's defenses [21].

Quality audit

- Implementation of an internal audit system: A systematic process of internal review of procedures and operations is established. This ensures compliance with quality standards and provides periodic evaluations of safety performance, transparency and effectiveness [22].

- Development of quality indicators: Relevant metrics and KPIs are defined to evaluate the service offered. These indicators, such as the success rate in the sale of bonds and the accuracy in the calculation of issues, allow continuous monitoring and the identification of areas for improvement.

- Implementation of a feedback system: A mechanism is established for users to report anomalies or problems. This feedback is key to identifying opportunities for improvement and adjusting processes and systems, ensuring high quality service and customer satisfaction.

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