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Social Metabolism Of Rice In Agro-Industrial Territories Of Colombia (2020–2024)

Metabolismo Social Del Arroz En Territorios Agroindustriales De Colombia (2020–2024)

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RESUMEN

El estudio analiza el metabolismo social del arroz en los territorios agroindustriales de Colombia durante 2020–2024, entendiendo el sistema arrocero como un entramado socio ecológico donde confluyen flujos materiales: agua, tierra, insumos y sociales: trabajo, capital, instituciones. Su objetivo general es examinar cómo estos flujos configuran y transforman los territorios productivos, afectando la sostenibilidad ambiental y la equidad territorial. La metodología combina un enfoque cualitativo–interpretativo con análisis descriptivo de datos productivos oficiales de Fedearroz y DANE, complementado con una interpretación socio ecológica basada en la teoría del metabolismo social. Los resultados evidencian estabilidad relativa del área cultivada, pero variabilidad significativa en rendimientos y producción, vinculada a la disponibilidad hídrica y al control de recursos. Se concluye que el sistema opera bajo una lógica de resiliencia productiva dependiente de la inversión tecnológica y del acceso al agua, reproduciendo

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desigualdades estructurales y una sostenibilidad parcial condicionada a factores económicos y ecológicos.

Palabras clave: Metabolismo social; Agroindustria arrocera; Sostenibilidad socio ecológica; Territorio rural; Recursos hídricos; Gobernanza agroindustrial.

ABSTRACT

This study analyzes the social metabolism of rice within Colombia's agro-industrial territories between 2020 and 2024, conceiving the rice sector as a socio-ecological system in which material flows (water, land, inputs) and social flows (labor, capital, institutions) converge. The general objective is to examine how these flows shape and transform productive territories, influencing environmental sustainability and territorial equity. The methodology combines a qualitative–interpretive approach with descriptive analysis of official production data from Fedearroz and DANE, complemented by a socio-ecological interpretation grounded in social metabolism theory. Results reveal relative stability in cultivated area but significant variability in yields and production, linked to water availability and resource control. It concludes that the system operates under a pattern of productive resilience dependent on technological investment and water access, reproducing structural inequalities and a partial form of sustainability conditioned by economic and ecological constraints.

Key words: Social metabolism; Rice agroindustry; Socio-ecological sustainability; Rural territory; Water resources; Agro-industrial governance.

INTRODUCCIÓN

Rice production in Colombia during the 2020–2024 period unfolds within a dynamic agro-industrial landscape in which territorial transformations, social relations, and resource flows converge to shape what can be termed the *social metabolism* of the crop (Rivera, 2022). In this context, the term *social metabolism* refers to the articulation between material flows—land, water, inputs, machinery, and product—and social processes—labor, commercialization, ownership structures, power relations, and institutions—that collectively transform the rural territory (Rodríguez, 2025a; Gómez, 2022). At the same time, the *agro-industrial* character of the rice sector entails a large-scale mode of production, intensive use of resources, and a strong linkage to both national and international markets, decisively influencing space, territory, and their actors (Infante et al., 2020; Kalmanovitz, 2019).

In agro-industrial territories, the rice value chain mobilizes not only planted hectares and harvested tonnage but also irrigation infrastructures, drainage systems, transport networks, storage and processing facilities, wage labor and subcontracting, as well as complex economic relationships among producers, processors, traders, and local communities (Kalmanovitz & López, 2006). This network of interdependencies generates a social metabolism that surpasses the individual plot: it constitutes a dense web of actors, inputs, infrastructures, and social forces which—through rice production—reconfigure the territory, produce environmental externalities such as water use, pollution, and land-use change, redistribute income, and in many cases intensify relations of dependency on agro-industrial capital (Gómez et al., 2025; Leff, 2004).

Delimiting the analysis to the 2020–2024 period, this article aims to examine how the social metabolism of rice in Colombia's agro-industrial territories has evolved, which material and social flows predominate, what territorial transformations have emerged, and what implications this dynamic holds for the socio-environmental sustainability of the sector (González de Molina & Toledo, 2011). The chosen timeframe captures the recent effects of agricultural policy, the COVID-19 pandemic, climatic variability, and organizational transformations within the sector (Sharafi et al., 2024; Barbosa et al., 2021). Likewise, focusing on the agro-industrial territorial sphere makes it possible to observe clearly how large-scale rice

production systems affect agrarian structure, water management, rural landscapes, and local communities (Albarracín et al., 2024; Padilla, et al., 2018; Infante et al., 2017).

Accordingly, the study first develops a conceptual framework articulating social metabolism, agro-industry, and territory; subsequently, it presents a table containing data on production, cultivated area, and yield for the 2020–2024 period. It then analyzes how these data are inscribed within the dynamics of social metabolism and finally discusses their implications for governance, territorial equity, and sustainability. Through this research exercise, the objective is not merely descriptive but analytical: to problematize how Colombia's rice agro-industry participates in processes of agrarian capital reproduction, the appropriation of natural resources such as water, and the transformation of territory—all mediated by social relations that structure the metabolism of the system (Urbano, 2023; Gutiérrez, et al., 2022; Rodríguez et al., 2021).

Conceptual framework

Social Metabolism

The concept of social metabolism refers to the idea that human societies not only produce knowledge, cultures, and social relations, but also metabolize that is, transform natural resources such as energy, raw materials, and products through economic, technological, and institutional processes (Vera y Castellanos, 2022; Púa, et al., 2022; González de Molina, 2016; Toledo, 2013). Within socioecological literature, social metabolism examines how material flows water, land, agricultural inputs, machinery, production intertwine with social flows labor, capital, markets, institutionsto shape production systems that are sustained over time (Blanco, et al., 2023; Gómez, 2021; Maldonado, 2018).

Agroindustry

Agroindustry is understood here as the phase of the agrarian system characterized by expanded productive scale, specialization, mechanization, and vertical integration production, transformation, and commercialization as a form of insertion into export markets or large-scale national markets (Bustillo, 2025; Gómez, 2025; Gélvez, et al., 2023). In the case of rice, agroindustry entails the intensive use of resources: land, water, chemical inputs, and energy, as well as the presence of business actors, irrigation and drainage infrastructure, logistics systems, and salaried or contracted workers (Rosero & Gómez, 2025;

Castellanos et al., 2023; Luna, et al., 2024; Carrillo, 2015).

Territory

The term territory refers to the geographic space in which the processes of social and agro-industrial metabolism unfold. It encompasses not only the agricultural plot but also the broader rural landscape, infrastructures such as irrigation networks, roads, and storage facilities local communities, the relationships among producers, and the ways in which space is organized and reorganized in accordance with productive activities (Gómez, 2024b; Escobar, 2015). The territory is transformed both physically through land-use changes, fragmentation, and infrastructure and socially through relations of power, access to resources, and water governance (Rodríguez, 2025b; Avendaño y Mosquera, 2022; Gudynas, 2021).

Articulation of the categories

The present research understands that the social metabolism of rice in agro-industrial territories implies that the rice agroindustry mobilizes material resources such as agricultural land, irrigation water, machinery, and inputs within a social framework composed of labor, commerce, institutions, and local communities, all situated in a territory that is continuously reconfigured in terms of landscape, infrastructure, and power (Alarcón, 2023; Lodice, 2015). Therefore, material flows cannot be understood in isolation from social flows or territorial transformation (Barrios et al., 2020).

The sustainability of the system environmental, social, and economic depends on how these three dimensions interrelate: how equitable access to resources such as water is, how diversified the local economy remains, and what territorial impacts arise from the expansion of rice cultivation (Urrego-Mesa et al., 2019; Martínez Alier, 2011).

Thus, this research proposes observing rice production in Colombia (2020–2024) as a system of social metabolism in which the rice agroindustry transforms territories, mobilizes resources, and configures specific social relations (Fedearroz, 2024). This approach enables not only the quantification of hectares and tonnage but also the analysis of power dynamics, access to resources, environmental impacts, and territorial disputes that emerge from agro-industrial production (La Rota-Aguilera et al., 2022; González de Molina, 2013).

Table 1. Characterization of rice production in Colombia (2020–2024)

year	Approximate Area planted (ha))	Approximate production (tons paddy)	Average yield (tons/ha)	Source
2020	630 000 ha	3 415 000 t	5.42 t/ha	Fedearroz (2024)
2021	625 000 ha	3 330 000 t	5.33 t/ha	Fedearroz (2024)
2022	620 000 ha	2 938 000 t	4.74 t/ha	Fedearroz (2024)
2023	628 000 ha	3 188 000 t	5.08 t/ha	DANE ENAM histórico
2024	631 000 ha	3 501 000 t	5.55 t/ha	Fedearroz (2024)

Source: Author's own elaboration based on (Fedearroz, 2024a; 2024b; Institute of Hydrology, Meteorology and Environmental Studies [IDEAM], 2024; Gómez, 2024a; Ministry of Commerce, Industry and Tourism – MinComercio, 2023; DANE, 2023; 2022).

MATERIALES Y MÉTODOS

The study adopted a qualitative–interpretive methodological approach supported by descriptive quantitative evidence, aimed at understanding the social metabolism of rice in Colombia as a socio-ecological system in constant transformation (Páramo, 2008). The qualitative perspective enabled the analysis of the social, economic, and territorial relations that structure rice production, while the descriptive component was grounded in the review and systematization of official production data (Maldonado, 2023; Bunge, 1997).

Accordingly, documentary and statistical analyses were conducted using sources such as the *National Survey of Mechanized Rice (ENAM)* by DANE and the Fedearroz databases corresponding to the 2020–2024 period (Barbosa et al., 2020). The systematization of these figures made it possible to identify variations in cultivated area, total production, and yields, forming the basis for interpreting processes of productive intensification, fluctuations in resource availability, and dynamics of

technological modernization (Camacho et al., 2023; Bryman, 2021).

Complementarily, a socio-ecological interpretation was undertaken, inspired by the theory of social metabolism, understood as the articulation between material and social flows. This approach enabled the positioning of productive data within historical structures of agrarian organization and the logics of capital accumulation associated with agroindustry (Rodríguez, 2024; Maldonado, 2014). Analytical triangulation among sectoral statistics, scientific literature, and institutional documents made it possible to identify patterns, trends, and structural tensions in the territorial configuration of rice production (Maldonado, 2024; Bunge, 1969). The purpose was not to establish linear causalities or quantitative determinisms but to comprehend how the rice agroindustry reconfigures territories, social relations, and strategic resources (Maldonado, 2017). Consequently, the unit of analysis was not the individual farm or producer but rather the national rice agro-industrial system, conceived as a social metabolism that articulates agricultural infrastructure, business organization, state policies, and territorial dynamics (Aguilera et al., 2020; Urrego-Mesa, 2018).

RESULTADOS Y DISCUSIÓN

The statistical analysis of the rice production system in Colombia during the 2020–2024 period reveals a relative stability in cultivated area, fluctuating between 620,000 and 631,000 hectares per year, indicating the consolidation of a mechanized, medium- to large-scale agro-industrial model (DANE, 2023; 2022). Nevertheless, total production and yields exhibited significant variations associated with factors such as water availability, climatic variability, international input prices—particularly nitrogen-based fertilizers—and the energy costs linked to water pumping and management (Fedearroz, 2024a; 2024b; Table 1).

The year 2022 represents a critical turning point within the analyzed period, registering a decrease of nearly 14% in

national production compared to 2021, and a drop in average yield to 4.7 t/ha, mainly due to localized droughts, increased agrochemical costs, and restrictions on certified seed renewal (MinComercio, 2023). However, the recovery observed in 2023 and 2024 resulted from a combination of technical adjustments such as genetic improvement, expanded technical assistance programs, greater adoption of pressurized irrigation in specific areas, and the partial stabilization of input markets. These measures enabled the resumption of yields exceeding 5.5 t/ha by 2024 (Escamilla et al., 2023; Gómez & Barreto, 2024).

These findings demonstrate that the social metabolism of rice in Colombia operates under a pattern of productive resilience dependent on technological investment capacity and control over strategic resources such as water (Guzmán et al., 2018). While technologically advanced producers manage to stabilize yields and mitigate losses, farmers with limited access to credit, irrigation infrastructure, and machinery face greater vulnerability and risk of exclusion from the productive system. This highlights a structural trend toward economic concentration in the sector, where productive stability is maintained at the cost of deepening inequalities in access to strategic resources (López, 2024; McDermott, 2022).

Discussion

The results show that between 2020 and 2024, rice production in Colombia maintained relative stability in cultivated area, although total production and yields experienced notable fluctuations (Novoa, 2024; Crespo & Pérez, 2018). These variations cannot be explained solely by climatic or technical factors but are embedded within an agro-industrial structure dependent on the intensive use of water and agrochemical inputs, as well as market dynamics that regulate prices, production costs, and access to capital (Rendón & Gómez, 2022; Gabriel, 2020). The production downturn observed in 2022 revealed the socio-ecological fragility of the system, particularly in response to water variability, rising fertilizer costs, and financial stress on

medium- and small-scale farmers (Taghdisian et al., 2022). This confirms that the rice agroindustry operates under a metabolic logic in which productive stability depends on the availability and control of strategic resources—especially water and land concentrated in the hands of actors with greater investment capacity (Martínez Alier, 2015).

In this sense, the rice agroindustry participates in territorial reorganization processes that tend toward the consolidation of technified monocultures, the expansion of irrigation systems, and the structuring of wage and outsourced labor chains (Vanegas, 2017; Bunge, 1980). This social metabolism produces agro-industrial territories functioning as highly specialized spaces oriented toward mass production, within which rural communities undergo significant transformations in their livelihoods, their relationship with water and land, and their possibilities for economic autonomy. Although the sector demonstrated technical resilience during 2023–2024 through genetic improvement, irrigation optimization, and mechanization, such resilience remained confined to the productive dimension, without necessarily implying improvements in labor conditions, equitable water access, or a transition toward environmentally sustainable practices (Vergara et al., 2025; Caixeta et al., 2018).

Thus, rice production in Colombia during the analyzed period can be characterized as a social metabolism that reproduces relations of dependency on agro-industrial capital while exerting pressure on natural resources and reconfiguring the socio-spatial structure of rural territories (Ramírez et al., 2020; Escobar, 2018). The sustainability of the system therefore appears partial and conditional: it depends on continued water access, stable input markets, and the capacity to maintain high levels of mechanization (Gutiérrez et al., 2024). The findings suggest that unless the socio-ecological and distributive tensions of the model are addressed, strategies of productive resilience may sustain the system in the short term but will not ensure its integral sustainability in the medium and long term (Martínez et al., 2024; Escobar, 2011).

CONCLUSIONES

Muestra correspondencia con los objetivos de la investigación y con los resultados obtenidos. Se exponen desde lo particular a lo general. No se debe describir, analizar ni discutir resultados. Deben ser concretos y preciso.

The social metabolism of rice in Colombia reveals an agro-industrial system structurally dependent on the concentration and control of key resources particularly water, land, and energy by a limited number of actors with high technological and financial capacity. This dependency reflects a metabolic asymmetry in which resource access determines productivity, resilience, and territorial influence. As a result, the sector reproduces historical patterns of agrarian inequality while reinforcing forms of ecological extraction that privilege efficiency over equity. The accumulation of capital in technologically advanced units sustains short-term competitiveness but deepens territorial disparities, compromising the long-term sustainability of rural livelihoods and ecosystems.

The analysis highlights that Colombia's rice agroindustry operates under a model of selective resilience a capacity to adapt to climatic and economic shocks through technological innovation, improved irrigation, and mechanization. However, this resilience is unequally distributed. While large producers integrate adaptive technologies and stabilize yields, small and medium farmers face increasing precarity due to limited access to capital, technical support, and institutional protection. Consequently, resilience becomes a mechanism of differentiation rather than inclusion, producing socio-ecological vulnerability. True sustainability, therefore, requires a shift from productivity-centered adaptation to socially equitable resilience that integrates participatory governance, redistributive mechanisms, and local knowledge systems.

Rice production, as a metabolic process, reshapes the rural territory beyond its productive function. It reorganizes landscapes through monoculture expansion, alters hydrological regimes

via intensive irrigation, and redefines labor structures through subcontracting and mechanization. These transformations intensify environmental pressures soil degradation, biodiversity loss, and water stress while modifying community relations and territorial identities. The study underscores that future sustainability must integrate territorial planning, environmental restoration, and water governance that recognizes ecosystems as active metabolic components rather than mere inputs. This implies transitioning from an extractive agro-industrial model toward a regenerative one grounded in ecological economics and social justice.

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