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Contribution of Voisin Rational Grazing and Buffalo Production to Strengthening Food Security and Ruminant Livestock Sustainability Facing Climate Change

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Abstract

The integration of alternative grazing systems and non-conventional livestock species in temperate mountain environments remains insufficiently understood. This study examined the integration of Voisin Rational Grazing (VRG) and water buffalo (*Bubalus bubalis*) production into livestock systems in Zacualtipán de Ángeles, Hidalgo, Mexico, focusing on interactions among local actors, production practices, and socio-institutional conditions. Guided by Hernán Thomas's socio-technical perspective, the study adopted an exploratory, interpretive qualitative design involving 31 key informants selected through snowball sampling. Data were collected through in-depth semi-structured interviews and examined using thematic and qualitative content analysis. The findings indicated substantial acceptance of VRG, with 67% direct agreement, which producers associated with pasture optimization, reduced feed costs, and improved herd management. Buffalo production, however, remained exploratory and fragmented, with reported interest of 40%. Market uncertainty, limited specialized technical assistance, and weak institutional support were identified as key barriers to its integration. These contrasting patterns contribute to socio-technical transition research by highlighting the uneven integration of grazing and livestock innovations within the same territorial setting. The study emphasizes the importance of cohesive socio-technical networks that connect production innovation with economic viability and ecosystem service conservation. Practical implications include

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tailored technical support and structured market development strategies. Future mixed-methods research could complement these findings by quantifying pasture characteristics and carbon sequestration.

Keywords: Voisin Rational Grazing; Water Buffalo Production; Sustainable Livestock Systems; Socio-Technical Transitions; Temperate Mountain Environments

INTRODUCTION

Grazing livestock production represents a fundamental economic activity in rural areas characterized by edaphoclimatic constraints and infrastructure limitations. Under these conditions, the efficient utilization of forage resources and the preservation of ecosystem services are crucial for the long-term sustainability of production systems. Understanding livestock farming through an integrated soil-plant-animal-climate framework helps identify management alternatives that overcome conventional schemes based on continuous grazing and progressive soil degradation (Milera-Rodríguez, 2021). Within this context, Voisin Rational Grazing (VRG) emerges as a management strategy grounded in the physiological principles of pasture plants. It prioritizes resting times, short paddock occupation periods, and planned stocking rates to maximize forage productivity without compromising the regenerative capacity of the ecosystem (Sorio Junior, 2006). The implementation of VRG has demonstrated positive effects on the recovery of plant carbohydrate reserves, sward stability, and overall livestock productivity, particularly in areas where continuous grazing has historically limited forage species persistence.

From an ecosystem services perspective, livestock systems managed under agroecological principles, such as VRG, enhance nutrient recycling, soil conservation, water regulation, and carbon sequestration. This is achieved by promoting high and homogeneous excreta deposition and stimulating soil biota activity (Milera-Rodríguez, 2021). Research on intensive rational grazing systems indicates favorable nutritional balances and a reduced reliance on external inputs, which in turn strengthens the resilience of the production system (Huerta et al., 2018; Domínguez-Escudero, 2020). Concurrently, water buffalo (*Bubalus bubalis*) production represents a strategic alternative within rational grazing systems due to the species' hardiness, its high efficiency in converting medium-quality fiber, and its capacity to comprehensively exploit different forage strata (Vale et al., 2013). Buffaloes exhibit lower dietary selectivity compared to cattle and a higher tolerance to limiting nutritional

environments, making them highly compatible with diversified pastoral systems that include fodder trees and shrubs (Iglesias et al., 2019).

Multiple studies have shown that water buffaloes prefer shaded systems, utilizing paddock trees and shrubs for both nutrition and thermoregulation, which reinforces their adaptation to silvopastorile and rational grazing designs (García et al., 2011). Research on tree species selection shows that buffaloes actively browse leguminous and multipurpose woody plants, which supply protein, minerals, and additional ecological benefits to the pasture ecosystem (Toral-Pérez et al., 2019). Experiences in Latin America indicate that integrating VRG with buffalo production improves productive efficiency, system stability, and soil preservation by accelerating nutrient cycling and enhancing edaphic biodiversity (Pinheiro-Machado, 2016; Milera-Rodríguez, 2021). However, scientific evidence regarding the joint application of these strategies in temperate mountain regions remains scarce, particularly in areas dominated by traditional livestock farming.

The municipality of Zacualtipán de Ángeles, Hidalgo, Mexico, provides an ideal setting to analyze Voisin Rational Grazing and water buffalo production as sustainable transition alternatives. Assessing these systems generates scientific data to understand their environmental and productive implications, as well as their potential contribution to local livestock sustainability. Consequently, this study is built on the premise that the viability and stabilization of these technologies depend not only on agronomic performance, but also on the relational dynamics and socio-technical alignment they achieve with local actor networks, traditional management practices, and current institutional frameworks. Therefore, the objective of this research is to analyze the incorporation of Voisin Rational Grazing and water buffalo production in the livestock systems of Zacualtipán de Ángeles, Hidalgo, focusing on their effects on pasture management, soil health, and associated ecosystem services.

General Objective

To analyze the incorporation processes of Voisin Rational Grazing (VRG) and water buffalo production among grazing ruminant producers in the Sierra Alta region of the state of Hidalgo, in order to identify challenges stemming from exclusive pasture use and the anticipated benefits of these systems for livestock sustainability.

Specific Objectives

● To characterize regional pasture management practices under traditional grazing.

● To identify Relevant Social Groups (RSGs), practices, technologies, and producers' knowledge regarding VRG and water buffalo management in the Sierra Alta of Hidalgo.

● To investigate the problems and solutions proposed by the RSGs for implementing VRG and buffalo production in their production units.

● To recognize the challenges associated with exclusive pasture feeding under traditional grazing systems.

● To analyze the socio-technical operation of VRG and water buffalo production in the Sierra Alta of Hidalgo, considering the interactions among local actors, productive practices, and knowledge systems.

METHODOLOGY

Research Type and Design

To address the research objectives and align with the theoretical framework, this study adopted a qualitative, exploratory, and interpretive research design. It focuses on understanding the meanings, practices, and relationships constructed by social actors surrounding the adoption of VRG and water buffaloes in Zacualtipán de Ángeles, Hidalgo, Mexico, analyzed through the lens of socio-technical trajectories and dynamics proposed by Hernán Thomas (1999).

Participants and Sampling Technique

The unit of analysis consisted of the livestock management practices deployed by producers in the municipality of Zacualtipán de Ángeles, Hidalgo. The study universe comprised actors directly or indirectly linked to grazing livestock production. A purposive sample of 31 key informants was selected using the snowball sampling technique to ensure representation across the local socio-technical network, distributed as follows:

● 15 ruminant livestock producers (cattle, sheep, and goats).

● 2 leaders of the local livestock association and the regional livestock union.

● 2 local meat market intermediaries.

- 2 regional agricultural input suppliers.
- 2 agricultural extension technicians with direct field operations.
- 2 institutional representatives from the public agricultural sector (SADER-DDR/CADER).
- 2 institutional technicians (Municipal Government and SADER).
- 3 independent advisors and experts in regenerative ranching.
- 1 scientific researcher specializing in sustainable animal production.

Spatially and temporally, the study covered the processes associated with the implementation of rational grazing and the introduction of buffaloes in the municipality over the last decade, referring to prior historical dynamics when required for interpretative clarity.

Instruments and Data Collection

Primary data were gathered through in-depth semi-structured interviews designed around key dimensions: producer experience, herd management practices, identified zootechnical constraints, implemented solutions, levels of theoretical and practical knowledge, and articulation with government agencies. For institutional representatives, technicians, and researchers, the inquiries focused on institutional support levels, programmatic limitations, and technical scalability.

Data validity and reliability were established through methodological triangulation, cross-referencing interview transcripts with secondary statistical sources and official databases. These included the Agricultural and Fisheries Information System (SIAP-SADER), active livestock registries from the National Individual Livestock Identification System (SINIIGA-SADER/CNOG), climate records from the National Meteorological Service (SMN), and peer-reviewed academic literature.

Data Analysis Technique

The transcribed interviews were analyzed using qualitative thematic and content analysis, guided by the socio-technical approach of Hernán Thomas (1999, 2009). Coding was structured around relational variables: socio-technical bottlenecks (regulatory, operational, geographical, or market barriers) and socio-technical alignments (strategic alliances, knowledge networks, subsidies, or mutual learning dynamics) that determine the functioning or non-functioning of the ecological innovations introduced in the Zacualtipán territory.

RESULTS

Interpretation of Results

In alignment with the qualitative interpretive methodology proposed by Irene Vasilachis (2019), the findings present the constructions of meaning emerging from the actors' discourses to evaluate the viability of the agroecological transition. Voisin Rational Grazing (VRG) and water buffalo integration are analyzed as socio-technical configurations in progress (Thomas, 1999, 2009). The results reveal two innovative pathways characterized by asymmetric stabilization dynamics.

Characterization of Relevant Social Groups

Under the socio-technical framework, Relevant Social Groups (RSGs) are defined by the meanings they attribute to a technology and their active role in supporting or hindering its stabilization within the territory. The findings show that the assimilation of VRG and buffalo production yields contrasting responses across RSGs due to heterogeneous socio-economic and cognitive priorities. While experts, researchers, and technicians view both innovations as essential tools for climate mitigation and environmental preservation, primary producers and market intermediaries operate under a framework of immediate financial viability and operational risk reduction.

Results on Voisin Rational Grazing (VRG)

Livestock Producers

Among the 15 interviewed livestock producers:

- 10 expressed clear agreement with integrating VRG into their farms.
- 3 conditioned their agreement on accessing preferential credit and continuous on-farm technical assistance.
- 2 showed resistance to the technological shift due to lack of information and the perception of high initial setup costs.

Producers who directly support VRG justified their stance based on pasture yield optimization, substantial reductions in commercial feed costs, and improved animal health control. This reveals a pragmatic approach to technology adoption, where the ecological benefits of soil conservation and water recharge are perceived as secondary positive externalities relative to economic survival. The operational barriers most frequently cited by

hesitant or conditional producers included the cost of paddock electrification (energizers and solar panels), the lack of local practical training, and the theft of infrastructure components in distant grazing areas.

Leaders of the Local Livestock Association and Regional Union

The 2 livestock association leaders expressed favorable views of VRG, acknowledging its potential to revitalize the regional pastoral sector during prolonged mountain droughts. However, they noted that structural land fragmentation (minifundia) and a weak culture of cooperation present significant barriers to the collective purchase of infrastructure inputs, such as high-tensile wire and posts.

Extension and Institutional Technicians

The 4 interviewed technicians (both field-level and institutional) showed complete agreement with VRG. They highlighted that planned grazing significantly improves the physical and microbiological properties of the soil, thereby increasing paddock carrying capacity and reducing grazing pressure on Zacualtipán's forested slopes. Nonetheless, they emphasized that the primary obstacle to widespread adoption is the absence of long-term, continuous training programs and the limited government budget allocated for rural extension.

Institutional Representatives of the Public Agricultural Sector (SADER-DDR/CADER)

The 2 institutional representatives acknowledged the zootechnical and ecological benefits of the rotational grazing model, showing interest in incorporating it into local sustainable development agendas. However, they clarified that the lack of specific operational rules to fund VRG infrastructure within active public programs, combined with the absence of local demonstration plots, limits the allocation of direct institutional funds for this practice.

Experts and Scientific Researcher

The 3 independent experts and the researcher agreed that VRG represents a mature, viable, and scientifically validated agroecological alternative. Their arguments emphasized that intensive rotational management stimulates sward biodiversity and optimizes organic carbon sequestration in the soil, equipping livestock units with superior resilience against climate anomalies.

Results on Water Buffalo Production

Livestock Producers

The integration pathway of water buffalo (*Bubalus bubalis*) exhibits fragmented assimilation and high levels of uncertainty:

- 6 producers showed active interest in buffalo farming, praising their zootechnical rusticity and excellent digestive performance on low-quality, high-fiber forage along humid mountain slopes.
- 5 expressed serious doubts regarding herd behavior, specialized reproductive management, and final product commercialization.
- 4 firmly rejected the introduction of the species, displaying resistance rooted in local myths of animal aggressiveness and fear of capital loss.

Meat Intermediaries

The 2 commercial intermediaries displayed caution and distrust. They explained that, in the absence of a stable supply chain or established local demand, buffalo meat represents a high financial risk. Local consumers are habituated to conventional beef and remain unfamiliar with the nutritional properties of buffalo meat.

Agricultural Input Suppliers

The 2 local suppliers indicated that the region lacks an established supply chain for specialized buffalo veterinary medicines, supplements, or zootechnical equipment. Although they expressed willingness to stock these products if a critical mass of buffalo producers emerges in Zacualtipán, the current absence of immediate commercial support heightens the perceived risk among interested farmers.

Technicians and Experts

The interviewed technicians and zootechnical experts validated the biological viability of buffaloes in humid, temperate mountain ecosystems, emphasizing their high feed conversion efficiency. However, they agreed that the lack of specialized technical assistance and structured local market channels restricts buffalo adoption to experimental or highly isolated units.

Comparison Between VRG and Buffalo Production

The comparative analysis, derived from the systematic coding of the RSGs'

discourses in Zacualtipán, Hidalgo, highlights divergent socio-technical dynamics, as detailed in Table 1.

Table 1. *Socio-technical dimensions of VRG and buffalo production in Zacualtipán, Hidalgo*

Evaluation Dimension	Voisin Rational Grazing (VRG)	Water Buffalo Production
Social Acceptance Level	High and consolidated (67% of producers in direct agreement)	Limited and emerging (40% of producers showing interest)
Primary Perceived Advantage	Pasture optimization and reduced operational costs	High rusticity and utilization of low-quality forage
Local Systemic Bottleneck	Cost of electric fences and paddock water infrastructure	Lack of formal local markets and commercial uncertainty
Technical Accompaniment	Moderately available through local extension agents	Absent; lack of expert veterinary and management support
Institutional Alignment	High potential; aligns with sustainable development programs	Weak; absence of specific public promotion policies
Socio-technical Phase	Advanced alignment of the local actor network	Exploratory phase with value chain disarticulation

Emerging Socio-technical Dynamics

The field study reveals three socio-technical configurations coexisting within Zacualtipán's livestock space: the traditional continuous grazing system, VRG as an innovation in an advanced phase of stabilization, and buffalo farming as an emerging innovation.

The trajectory of VRG benefits from a positive adoption momentum because it aligns with the cultural and historical identity of the traditional "cattle rancher," requiring changes in pasture management without disrupting the regional beef marketing structure. In contrast, the introduction of the water buffalo clashes with consumer cultural barriers, producer safety fears, and a highly fragile local value chain, resulting in a socio-technical blockade of the innovation.

DISCUSSION

The results obtained in the Sierra Alta of Hidalgo, Mexico, support the premise that agroecological livestock transitions are governed more by local social network cohesion and institutional backing than by the intrinsic biological or agronomic viability of the technologies (Thomas, 2009). This is evident when contrasting the acceptance of VRG (67%) with that of buffalo production (40%). VRG has successfully integrated because it aligns with the pre-existing cognitive structures and identities of traditional ruminant producers, whereas buffalo farming requires drastic changes in field management and the creation of new meat markets, encountering resistance due to high perceived financial risks.

The high value assigned to VRG for pasture agronomic optimization corresponds with the findings of Sorio Junior (2006) in Brazilian livestock production, which emphasize that the rigorous application of the four laws of grazing ensures maximum yield and forage longevity. Similarly, these results converge with those reported by Ballesteros et al. (2024) in the Colombian tropics, where intensive rational grazing demonstrated weight gains and carrying capacities that significantly reduced dependence on synthetic fertilizers and concentrated feeds, confirming that success lies in process-based biological management.

However, the limited public accompaniment detected in the Sierra of Hidalgo contrasts with the VRG experience in Honduras evaluated by Duque Montoya and Fonnegra Páez (2018). In that case, coordination among agricultural cooperatives, academia, and institutional support structured robust socio-technical networks, reducing uncertainty for smallholders. This demonstrates that scaling sustainable innovations requires local policymakers to formulate public policies adapted to territorial realities, rather than executing linear, generic technology transfers (Angel-Lozano et al., 2023; Maldonado-Enríquez & Montes-Sánchez, 2024).

Regarding water buffaloes, their high adaptability and digestive efficiency in utilizing fibrous resources under humid grazing and silvopastorile systems correlate with findings by Iglesias Gómez et al. (2019) and Toral-Pérez et al. (2019) in Cuba, where buffaloes outperformed conventional cattle in marginal environments. However, as noted by Mendoza et al. (2022) for Latin American tropical buffalo systems, if biological advantages are not supported by articulated markets and commercial security, high herd performance is insufficient to stabilize buffalo farming in rural communities.

Finally, while European scientific literature from consolidated economies—such as the analyses by Calabrò (2019) and Donnola (2019) in Italy—discusses rational grazing in relation to post-productivist demands for high-end animal welfare and organic niche markets, the producers of Zacualtipán reveal a highly pragmatic adoption pattern focused on cost reduction and household economic survival. This aligns with the subsistence agroecological perspective reported by Montoya Quintero (2019) in Colombia and Escudero (2019) in Panamanian hillside livestock systems.

Research Implications

This analysis provides a theoretical contribution to the sociology of technology and agroecological transition studies by demonstrating that the zootechnical superiority of an innovation is insufficient to guarantee its social diffusion if it does not align with local producer identities. Practically, the results indicate that sustainable livestock promotion policies must go beyond sporadic material subsidies. It is critical to design permanent, personalized technical accompaniment programs, strengthen local cooperative capacities, and implement educational campaigns to promote buffalo meat consumption at the regional level.

Limitations and Future Directions for Research

The qualitative nature of this study and its geographical focus on the municipality of Zacualtipán de Ángeles, Hidalgo, limit the direct quantitative generalization of the results to other regions of Mexico. To address this limitation, future research should adopt mixed-method designs. This would allow researchers to correlate qualitative narratives with biometric measurements of VRG pastures, precise carbon sequestration estimates, and dynamic financial simulations to calculate net economic returns for smallholders in mountain environments.

CONCLUSION

This study analyzed the adoption processes of Voisin Rational Grazing (VRG) and water buffalo production in Zacualtipán de Ángeles, Hidalgo, Mexico, from a socio-technical perspective. The findings reveal two highly asymmetric innovation trajectories coexisting within the territory. VRG represents an agroecological alternative in an advanced stage of socio-technical alignment, backed by 67% of local producers due to its direct benefits in

pasture yields and feed cost reductions, all within a framework that respects traditional cattle ranching identities.

Conversely, water buffalo production remains in an exploratory, fragmented phase (40% interest), held back by systemic bottlenecks including the absence of a structured meat market, consumer skepticism, a lack of specialized veterinary services, and weak institutional support in the Sierra of Hidalgo.

This research contributes to the field of agroecology and rural development by redefining sustainable livestock transitions as complex socio-technical alignments rather than simple, linear technology transfers. The biological and agronomic efficiencies of both pastures and animals depend on the collective construction of supportive organizational and commercial networks in the territory to achieve genuine sustainability and resilience against climate change.

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