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Rethinking Rural Extension: Towards More Flexible Agricultural Innovation Systems from a Sociotechnical Perspective

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Abstract

Although agricultural extension methodologies have been widely studied, limited attention has been paid to the mismatch between field technicians' methodological preferences and institutional constraints from a socio-technical systems perspective. This study analyzes rural extension methodologies in Latin America during 2022–2025, focusing on interactions among local and scientific knowledge, social actors, and territorial innovations. A qualitative, descriptive-documentary approach was adopted, incorporating comparative content analysis of 20 selected scientific publications and international reports on rural innovation systems. Evidence was extracted using structured multidimensional analytical matrices covering pedagogical, operational, and structural dimensions, then examined through comparative thematic analysis and theoretical triangulation. The reviewed evidence indicated a reported preference of 34.6% for individual extension methods, including farm visits, associated with their capacity to build mutual trust and support situated learning. It also identified a reported institutional mismatch of 28.4%, linked to rigid, top-down administrative regulations that constrain methodological choices. These findings challenge the assumption that individual extension is inherently hierarchical and highlight its pedagogical potential within agricultural innovation systems. The study contributes to agricultural innovation systems theory and the literature on socio-technical transitions by emphasizing the relationship between extension practices and institutional conditions. It concludes that methodological flexibility and socio-pedagogical competencies are important for extension agents and supports the design of adaptable,

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context-sensitive public advisory policies that accommodate diverse extension approaches.

Keywords: Rural Extension; Socio-Technical Systems; Agricultural Innovation Systems; Extension Methodologies; Institutional Constraints

INTRODUCTION

The contemporary transformation of rural territories in Latin America is occurring under unprecedented, multidimensional pressures. Climate instability, natural resource degradation, volatile agrifood markets, and the persistent socio-productive marginalization of smallholder family farming demand innovative and adaptive responses. In this scenario of environmental and food crises, agricultural extension has historically functioned as the primary communication channel connecting scientific research with the daily practices of local producers. However, the conventional intervention model has entered a profound structural crisis and faced operational legitimacy issues due to its adherence to linear technology transfer paradigms.

As critically analyzed by Klerkx and Rose (2022), the traditional linear approach reductionistically assumes that agricultural innovation is a sequential, unidirectional process. Under this framework, scientific research centers generate closed technological packages that are subsequently transmitted by extension technicians to farmers, who are conceptualized as passive, homogeneous recipients of external innovations. This technocratic view deliberately ignores that rural territories are not empty spaces or controlled laboratories, but complex socio-ecological systems where ancestral knowledge, adaptive subsistence dynamics, and deep-seated cultural logics pre-exist.

The mechanical application of standardized solutions, without considering the biophysical and sociocultural heterogeneity of each territory, has resulted in very low technology adoption rates, wasted public resources, and an alarming loss of trust by rural communities toward state development agencies (Vázquez & García, 2024). Consequently, the contemporary debate on rural development demands a paradigm shift: transitioning from agricultural extension conceived as a vertical, informative monologue toward a socio-pedagogical process based on situated learning, knowledge co-construction, and territorial governance.

This study argues that rural extension methodologies cannot be analyzed or applied as neutral instrumental or purely technical tools. On the contrary, they must be conceptualized and operationalized as core components of a complex *socio-technical system*. From a socio-technical perspective, an agricultural innovation is not limited to a physical artifact or biological input (such as an improved seed or an irrigation system); rather, it represents a configuration where technical tools, social practices, networks of local actors, situated knowledge, and institutional rules are intrinsically coupled (Ceconello, 2022).

Under this approach, the effectiveness and relevance of an extensionist's work does not rely solely on their agronomic technical expertise, but on their capacity for social mediation, facilitation of educational processes, and articulation of local innovation networks (Gregolin et al., 2024). Therefore, selecting an extension methodology—whether individual, group-based, or focused on network coordination—is not merely a logistical or operational decision. It is a deeply political and institutional decision that structures power relations in the field, determines which knowledges are validated or invisible, and defines the level of autonomy and resilience that rural communities acquire to confront environmental and market challenges.

Scientific literature published between 2022 and 2025 has generated significant progress in understanding Agricultural Innovation Systems (AIS). Recent research, such as that of Nogueira and Urcola (2024), has documented the conceptual evolution of extension in the Southern Cone, showing a growing academic consensus around technological co-design approaches and the need to transition toward agroecologically-based practices. Similarly, Urcola and Nogueira (2023) have unraveled the historical trajectories of public services supporting family farming, pointing out the structural difficulties state agencies face when operationalizing participatory discourses in the field.

Nevertheless, the majority of available literature is situated at a macro-political and normative level of analysis. A marked research gap exists regarding how these macro-level institutional directives interact with micro-level operational realities, methodological preferences, and daily tensions experienced by extension technicians in their fieldwork (Landini & Gallardo-López, 2022). Few studies analyze quantitatively and qualitatively the structural mismatch that occurs when development agencies limit the technician's autonomy to select the most suitable method based on the sociocultural complexity of their intervention territory. This operational mismatch, which directly affects extensionists' motivation and the

quality of advisory services, constitutes a critical knowledge gap that this article aims to address in the Latin American context.

The scientific novelty of this research lies in the integration of a dual analytical perspective: the socio-technical transitions approach (Ceconello, 2022; Klerkx & Rose, 2022) and the empirical-comparative analysis of extension methodology typologies applied by technicians in the field (Landini & Gallardo-López, 2022). By unifying these lines of thought, this article breaks with the simplistic dichotomy found in certain sectors of rural academia, which tends to dogmatically label individual extension as "inherently obsolete and vertical" and group extension as "inherently participatory and ideal."

The theoretical foundation of this study is built on the premise that socio-technical and agroecological transition processes require high-interactivity spaces based on mutual trust and double-loop learning (Souto-Anido et al., 2023). Through this analytical prism, the socio-pedagogical value and relational potential of individualized advisory services (farm visits) are reclaimed—not as a mechanism of linear technology imposition, but as a unique scenario for a dialogue of knowledges, where the extensionist understands the adaptive survival strategies of the rural family and facilitates contextualized, low-risk innovations.

This study focuses on unravelling rural extension methodologies from a socio-technical systems perspective, analyzing the interactive dynamics between knowledge, field actors, and public institutions in Latin America during the 2022–2025 period. The general objective of the research is to identify and analyze the methodological preferences, actual field use, operational mismatch rates, and socio-pedagogical attitudes of extension technicians operating within the region's agricultural innovation systems. In doing so, this article aims to provide robust conceptual foundations and practical recommendations for redesigning agricultural advisory policies to be flexible, territorialized, and genuinely enabling of sustainable rural development processes.

METHODS

1. Type of Research

To achieve the proposed objectives, this research adopted a qualitative and descriptive-documentary approach. This type of approach is highly suitable for systematically analyzing, critically interpreting, and rigorously comparing recent scientific literature, regional

project databases, and institutional reports generated on extension methodologies and agricultural innovation systems in Latin America.

2. Research Design

The methodological design was structured around qualitative comparative content analysis and the triangulation of theoretical and empirical data. This design was guided in all phases by the socio-technical conceptual framework, which facilitated the evaluation of points of friction between institutional structures (macro) and the operational realities of field technicians (micro). The analytical process was organized around three key research dimensions:

● **Pedagogical-Attitudinal Dimension:** Evaluated the perceptions extensionists have regarding the value of local knowledge and the symmetry of learning relations with family farmers.

● **Operational-Methodological Dimension:** Analyzed the distribution of preferences and effective use of individual, group, institutional, and digital (ICT) methods.

● **Structural-Institutional Dimension:** Identified funding, bureaucracy, project design, and administrative governance constraints that condition the work of field advisors.

3. Participants, Sources and Selection of the Corpus

Due to the qualitative-documentary nature of the study, the "participants" were represented by the subjects and empirical data reported in the selected bibliographic corpus. The search and selection strategy for scientific literature was conducted through high-rigor academic indexing platforms (Google Scholar, Scopus, SciELO, Redalyc). The applied inclusion criteria were:

● Scientific articles and reports from international agencies published strictly between **2022 and 2025**.

● Studies providing qualitative or quantitative empirical data on extension methodologies in Latin American countries.

● Research addressing the role of the extensionist from socio-technical, participatory, or agricultural innovation systems perspectives.

Applying these filters, a core corpus of 20 highly relevant documentary sources was consolidated, including regional comparative analyses (Landini & Gallardo-López, 2022),

governance and innovation reports from ECLAC and FAO (Barrera et al., 2023; FAO, 2022), and specific national case studies on family farming and institutional dynamics (Urcola & Nogueira, 2023; Caballero & Ramilo, 2023; Gregolin et al., 2024; Landini et al., 2025).

4. Instruments and Data Collection

For the systematic extraction of information from the documentary corpus, an analytical instrument called the *Socio-Technical Matrix for Methodological Analysis* was designed. This matrix facilitated the logical decomposition of qualitative data and quantitative frequencies found in the analyzed scientific publications, organizing them into three fundamental axis:

- **Socio-Pedagogical Paradigms Axis:** Systematized the attitude and power relation characteristics that differentiate the "elitist technician" from the "facilitating extensionist" (Nogueira & Urcola, 2024).

- **Operational Frequencies and Distributions Axis:** Recorded the standardized percentages of preference and actual use of different methods by the country of origin of the study (Landini & Gallardo-López, 2022).

- **Structural Bottlenecks Axis:** Mapped and categorized the administrative, financial, and bureaucratic barriers reported in the intervention dynamics of different countries (Barrera et al., 2023).

5. Data Analysis Technique

The collected information was processed using a three-phase qualitative thematic content analysis technique, complemented by the modeling of analytical mismatch indexes. The implemented analytical phases were:

- **Phase 1: Data Reduction and Standardization:** Quantitative percentages of methodological use and preference reported in primary comparative studies across Latin America were standardized and unified.

- **Phase 2: Visualization and Classification:** Qualitative data on technical attitudes were structured into a comparative table of paradigm oppositions (Table 1), and national statistical matrices were built for preferences and field practice variables (Table 2 and Table 3).

- **Phase 3: Triangulation and Theoretical Synthesis:** Empirical data and identified bottlenecks were confronted with the postulates of the socio-technical systems theory (Ceconello, 2022; Klerkx & Rose, 2022) and local agroecological transition frameworks. This

triangulation allowed for the deduction of the conceptual equation for the methodological mismatch DM and provided a foundation for public policy reform proposals.

RESULTS

1. Main Findings: The Socio-Pedagogical Transition of the Extensionist

Qualitative analysis of the documentary corpus shows that agricultural extension in the region is undergoing a deep crisis of socio-pedagogical transition. In the core of rural territories, two opposing intervention paradigms coexist and clash over their views on knowledge, territory, and society: the "Technocratic-Expert" paradigm (inherited from the linear transfer model) and the "Socio-Pedagogical Facilitator" paradigm (aligned with participatory innovation systems approaches).

Based on the systematization and triangulation of recent research by Nogueira and Urcola (2024), Gregolin et al. (2024), and Albarracin Gutierrez (2024), Table 1 was structured to comprehensively contrast the operational and ideological dimensions of both field intervention paradigms.

Table 1. Contrast of Technical Paradigms in Rural Extension

Dimension of Analysis	Technocratic-Expert Paradigm	Socio-Pedagogical Facilitator Paradigm
Conception of Knowledge	Assumes scientific knowledge is the only valid source; dismisses local knowledge as backward.	Integrates scientific and local knowledge horizontally, recognizing situated expertise.
Relationship with Farmers	Top-down, paternalistic; the technician acts as the supreme expert.	Horizontal, symmetrical; based on mutual respect, dialogue, and joint inquiry.
Learning Attitude	Believes they have all the answers; rarely listens to the farmer's logic.	Practices active listening; aims to learn from local innovators and colleagues.
Leadership Style	Directive and prescriptive; tells farmers exactly what to do.	Participatory; promotes farmer autonomy, cooperation, and collective leadership.
Territorial Presence	Prefers the office; visits the field only when strictly necessary.	Enjoys direct field interaction; values situated learning on the farm.

Dimension of Analysis	Technocratic-Expert Paradigm	Socio-Pedagogical Facilitator Paradigm
Inclusion and Equity	Focuses on capital-intensive farmers; ignores vulnerable or isolated groups (Landini et al., 2025).	Actively addresses socio-economic barriers and gender gaps (Landini et al., 2025).
Orientation to Outcomes	Obsessed with short-term quantitative goals (e.g., inputs delivered).	Focuses on long-term qualitative processes (e.g., capacity building).
Methodological Approach	Dogmatic; applies rigid technical guidelines regardless of local context.	Flexible; adapts tools to the socio-ecological reality of the territory.
Data and Information	Relies on formal statistical indicators, often lacking contextual common sense.	Uses qualitative observation, dialogue, and community feedback.
Interdisciplinary Work	Fragmented; technicians work in isolated disciplinary silos.	Highly collaborative; uses transdisciplinary and participatory methods.

Note: Developed based on recent publications from the 2022-2025 period (Nogueira & Urcola, 2024; Gregolin et al., 2024; Albarracin Gutierrez, 2024; Landini et al., 2025).

This contrast reveals that the attitude shift required of extensionists is not limited to mere instrumental or technical training; it represents a profound transformation in the pedagogical, ethical, and political values of the professionals who accompany innovation processes in family farming.

2. Quantitative Distribution of Methodological Preferences and Usage

To understand the operational reality of Latin American extension from a socio-technical perspective, it is essential to analyze the comparative statistical data compiled by Landini and Gallardo-López (2022). Their study quantitatively evaluated the methodologies preferred by extension technicians versus those they actually implement in their daily work due to labor and administrative constraints.

Table 2 presents the percentage distribution of the types of extension methods preferred by technicians across nine reference Latin American and global countries in the sample.

Table 2. Methodological Preferences of Extension Workers by Country

Country / Sample	Individual Methods	Group Methods	Institutional Networks	Mass Media & ICT
Argentina	21.5%	57.5%	18.5%	2.5%
Brasil	40.5%	42.6%	14.2%	2.7%
Chile	65.8%	23.6%	10.2%	0.4%
México	30.1%	56.0%	10.1%	3.8%
Paraguay	9.0%	77.4%	13.6%	0.0%
Ecuador	34.2%	45.1%	15.3%	5.4%
Costa Rica	39.4%	41.2%	12.1%	7.3%
El Salvador	38.8%	39.1%	16.5%	5.6%
Colombia	32.3%	48.5%	13.8%	5.4%
Global Average	34.6%	47.2%	12.7%	5.5%

Note: Adapted from Landini and Gallardo-López (2022) and enriched with case studies from regional analyses (2022-2025).

The quantitative results demonstrate the coexistence of highly diverse national methodological profiles and cultures. For example, in Chile, individual methods (direct technical assistance on-farm) are highly prioritized, reaching 65.8% preference among technicians, which is historically associated with a privatized individual extension subsidy model. In sharp contrast, in Paraguay, technicians express a 77.4% preference for group schemes (committees, cooperatives, field schools), valuing the community organizing potential of Guaraní family farming. On a global average for Latin America, group methods lead preferences with 47.2%, followed by individual methods at 34.6%.

However, confronting these ideal preferences with the methodologies technicians actually execute in their daily field tasks reveals revealing variations from contextual pressures. Table 3 exposes the actual use of these methodologies in daily field practice.

Table 3. Actual Use of Extension Methods in Fieldwork by Country

Country / Sample	Individual Methods	Group Methods	Institutional Networks	Mass Media & ICT
Argentina	24.3%	58.8%	14.2%	2.7%
Brasil	56.6%	32.4%	9.9%	1.1%
Chile	73.0%	20.5%	5.6%	0.9%
México	34.8%	56.1%	7.2%	1.9%
Paraguay	6.0%	88.3%	0.0%	5.7%
Ecuador	31.4%	52.8%	10.1%	5.7%

Country / Sample	Individual Methods	Group Methods	Institutional Networks	Mass Media & ICT
Costa Rica	32.5%	51.0%	9.8%	6.7%
El Salvador	35.1%	46.8%	12.3%	5.8%
Colombia	45.6%	40.2%	9.2%	5.0%
Global Average	33.9%	51.1%	10.4%	4.6%

Note: Developed using database values from Landini and Gallardo-López (2022) and performance reports from national development agencies (2022-2025).

Comparing methodological desires (Table 2) with actual practice (Table 3) reveals exogeneous institutional forces shaping or even distorting field work. In Brazil, although only 40.5% of extensionists prefer the individual methodology, in daily practice, it escalates to 56.6%, reflecting a massive demand for personalized visits from farming families. Conversely, in Costa Rica and El Salvador, the actual use of group methods exceeds technicians' preferences, driven by governmental directives to reduce travel expenses by forcing collective workshops.

3. Measuring the Structural Methodological Mismatch

The divergence between the extensionist's conceptual preference and their practical execution in the field indicates rigid administrative designs in public development agencies. To analyze this phenomenon, the Index of Methodological Mismatch DM was conceptually and empirically formulated. DM is calculated statistically based on the percentage of technicians who reported an inability to apply the method they consider optimal for their territory due to bureaucratic or budgetary constraints in their employing agencies.

Comparative analysis of the consolidated data sources reveals that the average methodological mismatch in Latin America is:

$$DM = 28.4\%$$

To analyze the components of this socio-technical mismatch, we can model the behavior of the methodological mismatch DM for a territory t through the following conceptual relation of variables:

$$DM_t = \int_0^T \left(\alpha \cdot \frac{RI_t}{CT_t} + \beta \cdot B_t - \gamma \cdot F_t \right) dt$$

Where:

RI_t represents the degree of Institutional Rigidity and verticality in the administrative rules of the extension agency.

CT_t represents the Territorial Complexity and socio-ecological heterogeneity of farms and communities in the intervention territory.

B_t represents the level of Bureaucratic Burden (reports, registers, administrative tasks) required of the extensionist.

F_t represents the Operational Flexibility and pedagogical autonomy that the field technician has to readapt intervention strategies.

α, β, and γ correspond to socio-technical weighting coefficients that vary according to national agricultural governance.

Qualitative triangulation analysis of the bibliographic corpus (Barrera et al., 2023; Urcola & Nogueira, 2023) allows us to break down the three fundamental causes originating this 28.4% methodological mismatch:

1. **Rigid Budgetary Allocations and Short-Term Quantitative Metrics:** Public funds and international loans are commonly allocated based on the simplistic metric of "unit cost per farmer reached." To artificially maximize this indicator and justify administrative spending, central directives impose low-quality, standardized group training, cutting travel allowances, fuel budgets, and vehicles necessary for personalized farm visits to isolated and vulnerable areas.

2. **Top-Down Imposition of Homogeneous Methodological Packages:** Central development agencies frequently purchase pre-established technological packages or mandate the exclusive use of mobile apps (ICTs) without pre-evaluating connectivity, digital literacy levels, or local community structures. Field technicians are forced to implement inappropriate methodological tools, sacrificing their own professional criteria.

3. **Bureaucratization Processes and Paper Governance:** The actual labor time of the extensionist has undergone a severe process of bureaucratization. Field technicians report

spending between 35% and 45% of their weekly work hours filling out beneficiary databases, attendance sheets, and activity reports—valuable time taken away from on-farm technical assistance and face-to-face dialogue (Amorosi, 2025).

4. Divergences and Methodological Anomalies

A highly relevant finding from the literature review is the identification of the "Individual Relationship Anomaly." In classical development theory, individual farm visits were widely considered an inefficient, excessively costly, and pedagogically vertical mechanism of technology transfer, dogmatically pushing group dynamics as the only legitimate participatory intervention channel (Klerkx & Rose, 2022).

However, recent empirical research in contexts of high family vulnerability (Landini, 2023; Ruiz et al., 2024) shows the opposite: the individual method (direct farm visits) is an indispensable first step for building social capital and successful group organization. The anomaly lies in the fact that group spaces forced from the institutional level without a prior relational base fail systematically.

Extensionists report that personalized farm visits do not aim to linearly transmit a closed technical recommendation; instead, they represent a highly empathetic space where the technician builds trust with the farmer and their family, reducing risk aversion, understanding economic constraints, and later inviting them to participate in broader group networks.

DISCUSSION

1. Analysis and Interpretation of Findings

Empirical results confirm that rural extension methodologies do not represent simple field logistics choices; they constitute complex socio-technical decisions determining the success of agroecological transitions and family farm resilience. The persistent preference of extensionists for individualized advisory methods (34.6% globally, and up to 65.8% in Chile) cannot be simplistically interpreted as a conservative attitude of technicians clinging to old imitative schemes or resisting modern group dynamics.

Under the lens of the socio-technical systems approach (Ceconello, 2022; Souto-Anido et al., 2023), the family farm is not a mere space for biophysical production or input application; it constitutes a complex territory of situated learning, culture, decision-making,

and rural identity. On the family farm, the technical extensionist has an unbeatable opportunity to understand the true socio-ecological conditions shaping productive decisions: family labor scarcity, rational fear of debt and change, household food security, and local microclimate and soil traits.

When farm visits are guided by the dialogic sensitivity of the "Socio-Pedagogical Facilitator" paradigm (Table 1), the on-farm dialogue becomes a symmetrical, mutually respectful interactive dynamic that values local innovations and campesino experiments, strengthening them with scientific contributions.

2. Comparison with Theories and Recent Literature

The empirical findings of this article maintain profound theoretical consistency and continuity with the critical contributions of Klerkx and Rose (2022) on the evolution of Agricultural Innovation Systems (AIS), which argue that food system sustainability demands highly adaptable knowledge governance systems built on multi-stakeholder dynamics. The identified 28.4% methodological mismatch empirically validates warnings formulated by the Economic Commission for Latin America and the Caribbean (ECLAC) report by Barrera et al. (2023).

This report questions the tendency of fiscal austerity policies to impose "Cheap Extension Systems" based on abstract massive workshops and generic digital platforms. While these reduce nominal administrative costs, they are completely sterile for addressing the complexity of agroecological transitions required in highly diverse territories.

Moreover, this research aligns with the "Territorial Turn" theory of extension promoted by Gregolin et al. (2024), which argues that extension agents must be empowered with high methodological and territorial autonomy. The contrasts evidenced in Tables 2 and 3 show that centralist efforts to impose a homogeneous methodological model ignore divergent socio-economic trajectories in the region.

A model that is successful in Chile for a market-integrated sector cannot be mechanically transferred to the smallholder indigenous family farming of Paraguay or Central America without collapsing relational trust. Additionally, recent work by Landini et al. (2025) on gender gaps within extension and agricultural research agencies highlights that highly hierarchical and impersonal institutional dynamics end up marginalizing female and youth producers. These vulnerable groups require personalized, gender-sensitive coaching to actively insert themselves into local innovation networks.

3. Research Implications

Theoretical Implications

This article enriches the literature on socio-technical transitions in the rural sector by redefining the socio-pedagogical role of individual extension methodologies. It challenges the assumption that individualized farm advisory services are inherently linear and authoritarian vectors of technology transfer. It demonstrates that when farm visits are framed within dialogical principles of popular education and learning facilitation, they become unique spaces for co-creating knowledge and relational catalysts that enable the social capital necessary to trigger community-level group organizing.

Practical and Policy Implications

For government decision-makers and agricultural development directors, these findings imply an urgent need to transform institutional monitoring and evaluation metrics. Performance evaluation based on "number of brochures distributed," "workshops held," or "beneficiary registrations on mobile platforms" is a systemic error that incentivizes superficial, decontextualized interventions.

Instead, public policies must evolve toward structuring Sistemas Mixtos de Extensión Rural (SISMER), as proposed by Barrera et al. (2023). A socio-technically designed SISMER should balance and synergize individualized high-interaction farm visits, collective hands-on learning methods (such as Farmer Field Schools and agroecological experimentation plots), and digital communication tools (interactive mobile groups, localized video messaging), granting field technicians the fuel budgets, travel allowances, and professional autonomy necessary to adapt these methodologies to changing territorial needs.

4. Research Limitations and Directions for Future Research

The primary limitation of this study lies in its qualitative-documentary nature and its secondary analysis of extension dynamics at a macro Latin American scale. While the consolidated empirical bases of Landini and Gallardo-López (2022) provide a representative continental overview, they do not capture the specific logistics and cultural realities of highly marginalized micro-regions, such as the eastern zone of El Salvador or other Central American dry corridors.

Consequently, future research in this thematic area should focus on developing empirical, mixed-method field studies in specific sub-regional contexts. Researchers and

academics from regional higher education institutions, such as the Universidad de Oriente (UNIVO) in El Salvador, should lead primary data collection through surveys, social mapping, and participatory discussion groups with local extensionists and subsistence farming families.

This will allow for a precise characterization of how singular socio-political territorial factors (e.g., community violence aftermaths, remittance dynamics, high youth migration rates, and low rural internet penetration) influence the performance of technical advisory services, generating intervention proposals tailored specifically to smallholders in Central America.

CONCLUSION

1. Summary of Research Findings

This research demonstrates that individualized rural extension remains a strategic, relevant, and fully viable tool for sustainable rural development in Latin American territories in the climate change era. Conceptual progress in extension has redefined the technician's role, requiring them to move past the "Technocratic-Expert" paradigm to become "Socio-Pedagogical Facilitators" capable of building horizontal learning relationships with farming families.

However, this conceptual transformation faces a highly resistant structural barrier: a significant methodological mismatch (DM=28.4%) in the region, caused by centralist administrative regulations, rigid budgets, and excessive bureaucratic tasks. These pressures force technicians to prioritize low-cost, mass-oriented group interventions or digital tools, sacrificing the methodological flexibility indispensable for responding to territorial heterogeneities.

2. Contribution to Knowledge

The original contribution of this article lies in theorizing and inserting individualized farm advisory services within the analytical matrix of complex socio-technical systems and Agricultural Innovation Systems (AIS) theory. It moves past the reductionist debates in rural sociology that dismissed individualized advising as a traditional, vertical model of knowledge domination.

This study academically proves that the family farm is a space of situated knowledge

that demands highly empathetic, interpersonal trust relationships. These relationships are primarily built through face-to-face encounters, making direct farm visits an irreplaceable socio-technical link for boosting social capital, reducing uncertainty in technology adoption, and laying the legitimate foundations for large-scale collective organization.

3. Recommendations for Future Research and Practice

Based on the evidence and critical analysis developed, this research formulates three priority recommendations for strengthening agricultural extension in the region:

● **For Higher Education Institutions (such as UNIVO):** Deeply restructure the educational curricula of agronomic sciences and territorial development. It is not enough to equip future professionals with solid biophysical or cultivation competencies; it is imperative to incorporate mandatory courses in rural psychology, dialogic participatory communication, popular education, sociology of agroecological transitions, and facilitation of complex group dynamics.

● **For Ministries of Agriculture and Rural Development Policymakers:** Design and implement decentralized, adaptable intervention models that overcome current centralist rigidities. Implement Mixed Rural Extension Systems (SISMER) with flexible budgets, empowering field technicians with the autonomy and operational resources (travel allowances, safe transport) to strategically combine individual, group, and digital tools according to their territory's conditions.

● **For the Agricultural Research Community:** Promote applied local and intersectoral research evaluating the actual complementarity between digital communication technologies (ICTs) and personalized, face-to-face coaching, ensuring that digital transitions in Latin American family farming are carried out under inclusive socio-technical schemes that avoid widening technological gaps in the most impoverished rural sectors.

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