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Research Article

# Grassroots Social Innovation for Circular Economy Transitions: Assessing the Interplay Between Social Capital and Governance in Community-Led Initiatives

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## Abstract

Grassroots social innovation has become increasingly important in advancing circular economy transitions, yet limited evidence explains how social capital and governance jointly shape the performance of community-led initiatives. This study examined the interaction between bonding, bridging, and linking social capital and participatory governance in determining organizational resilience, social inclusion, and circular economy outcomes. A convergent mixed-methods multiple-case design was employed across twelve community-led initiatives. Quantitative data were collected from 240 participants through structured questionnaires, while qualitative evidence was obtained from thirty-six key informants, nonparticipant observations, and organizational documents. Descriptive statistics, correlation analysis, hierarchical regression, thematic analysis, and cross-case comparison were applied. The findings showed that social capital, governance quality, and community participation were positively associated with initiative performance. Governance quality exerted a stronger direct effect than social capital, while their interaction significantly improved organizational and environmental outcomes. Initiatives combining internal trust, diversified external networks, transparent leadership, and institutional support demonstrated greater continuity and broader social benefits.

**Keywords**: Circular Economy, Community Governance, Grassroots Innovation.

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## INTRODUCTION

The accelerating depletion of natural resources, rising volumes of municipal waste, and intensifying ecological pressures have strengthened the urgency of transitioning from linear production and consumption systems toward a circular economy (Mahin et al., 2026; Sedita et al., 2026; Urueña & Rodríguez, 2026). Conventional economic models generally follow a take–make–use–dispose pattern that treats natural resources as abundant and waste as an unavoidable consequence of economic growth. A circular economy challenges this assumption by promoting resource efficiency, product longevity, reuse, repair, recycling, sharing, and material recovery . Current discussions increasingly acknowledge that circular transitions cannot be achieved solely through technological innovation, industrial restructuring, or national regulation. Social practices, community participation, cultural norms, and locally embedded forms of cooperation are equally important because circularity ultimately depends on changes in how people produce, consume, exchange, and manage resources.

Grassroots social innovation has emerged as a promising pathway for translating circular economy principles into locally relevant practices. Community-led initiatives such as repair cafés, waste banks, community composting programs, cooperative recycling centers, tool-sharing networks, local food systems, upcycling enterprises, and neighborhood reuse platforms demonstrate how citizens can collectively respond to environmental and socioeconomic challenges (Masali et al., 2026; Schmidt et al., 2026; Torres-Navarrete et al., 2026). These initiatives often begin outside formal market structures and governmental programs, relying instead on local knowledge, volunteerism, mutual assistance, and shared environmental concerns. Their significance extends beyond waste reduction because they may also generate employment, strengthen community cohesion, improve access to resources, and encourage more democratic forms of environmental action. Grassroots initiatives can therefore be understood as experimental spaces where circular economy practices are adapted to specific social, cultural, and territorial conditions.

The effectiveness and continuity of grassroots circular initiatives remain strongly influenced by the social and institutional environments in which they operate. Social capital provides relationships, trust, shared norms, reciprocity, and networks that enable community members to coordinate collective action (Echarte et al., 2026; Leal Filho et al., 2026; Li et al., 2026). Governance determines how authority, resources, responsibilities, rules, and decision-making processes are organized among citizens, community organizations, public institutions, private actors, and civil society groups. Strong community networks may encourage participation and resource sharing, yet informal cooperation alone may not provide adequate financial support, legal recognition, technical assistance, or long-term institutional stability. The intersection between social capital and governance consequently becomes central to understanding why some community-led circular economy initiatives expand and endure while others remain fragmented, dependent on individuals, or vulnerable to organizational decline.

Community-led circular economy initiatives frequently face difficulties in sustaining participation after the initial enthusiasm has declined (Abrantes et al., 2026; Lara-Llanderal & Cedano-Villavicencio, 2026; Osei et al., 2026). Volunteer fatigue, unequal distribution of responsibilities, limited managerial capacity, weak access to infrastructure, and dependence on a small number of committed individuals can restrict organizational continuity. Trust and solidarity may help communities mobilize during the early stages of an initiative, but these resources do not automatically produce stable institutional arrangements. Some groups may possess dense internal relationships while remaining disconnected from external networks that provide funding, expertise, policy support, or market access. The central problem is therefore not merely whether social capital exists, but whether different forms of social capital can be converted into durable organizational capacity and meaningful circular economy outcomes.

Governance arrangements present another major challenge because grassroots initiatives operate across multiple institutional levels and regulatory environments. Local governments

may publicly support sustainability while maintaining administrative procedures that are difficult for small community organizations to navigate (Ahmadi Dehrashid et al., 2026; Firoozi et al., 2026; Soh, 2026). Public agencies may also treat communities as program beneficiaries rather than partners with legitimate knowledge and decision-making authority. Private-sector actors may offer resources or market connections, yet their priorities can shift attention from social and environmental objectives toward commercial performance. Fragmented responsibilities among government agencies, community groups, businesses, and nongovernmental organizations can create uncertainty concerning ownership, accountability, financing, and operational authority. These conditions indicate that governance quality involves more than formal policy support; it also requires inclusive participation, transparent decision-making, institutional coordination, and responsiveness to local needs.

Limited understanding of the interaction between social capital and governance restricts the ability of researchers and policymakers to explain the varied trajectories of community-led circular initiatives (Albers et al., 2026; Cantoni et al., 2026; Ozcan & Acikgoz, 2026). High levels of internal trust may strengthen collective identity while unintentionally excluding newcomers, minority groups, or less influential residents. Formal governance support may provide legitimacy and funding while reducing community autonomy through excessive administrative control. Collaborative governance may broaden access to resources, yet power imbalances can allow government institutions or private actors to dominate decision-making processes. Research that examines social capital and governance as separate variables may overlook these tensions. A relational assessment is needed to determine how community networks and governance arrangements reinforce, constrain, or reshape one another throughout the development of grassroots circular economy initiatives.

The primary objective of this study is to assess how social capital and governance interact in shaping the formation, operation, sustainability, and transformative potential of community-led circular economy initiatives (Chygryn et al., 2026; Sievers et al., 2026; Vafadari Komarolya & Sajedi, 2026). The study seeks to examine the mechanisms through which trust, reciprocity, shared norms, collective identity, and social networks support citizen participation and coordinated resource management. Attention will be given to bonding social capital within relatively close community groups, bridging social capital across diverse social groups, and linking social capital between community actors and institutions with greater authority or resources. This objective will clarify which forms of social capital are most relevant at different stages of grassroots innovation.

The second objective is to analyze the governance structures surrounding community-led initiatives, including internal decision-making systems and relationships with external institutions (Carayannis et al., 2026; Civera et al., 2026; Healy et al., 2026). The analysis will consider the distribution of authority, stakeholder participation, transparency, accountability, access to resources, policy recognition, and mechanisms for resolving conflict. Particular attention will be directed toward the ways local governments, nonprofit organizations, businesses, academic institutions, and community leaders influence the autonomy and capacity of grassroots initiatives. The study aims to determine whether governance arrangements function as enabling structures that support community experimentation or as restrictive systems that impose administrative burdens and reinforce unequal power relations.

The third objective is to develop an integrated analytical explanation of the conditions under which grassroots social innovations can contribute to broader circular economy transitions. The research will identify combinations of social and institutional factors associated with stronger participation, organizational resilience, resource circulation, social inclusion, and potential replication (Asprilla-Echeverria, 2026; Sumra et al., 2026; Wu et al., 2026). The intended outcome is not only a description of successful initiatives, but also a clearer understanding of causal and relational processes. The study is expected to produce practical insights for designing governance approaches that preserve community ownership

while connecting local initiatives to wider policy frameworks, financial resources, technical knowledge, and circular value networks.

Existing circular economy literature has predominantly emphasized technological efficiency, eco-design, industrial symbiosis, business models, supply-chain innovation, and regulatory instruments (Heuzé & Gianoli, 2026; Ruj & Majumdar, 2026; Trotta et al., 2026). This body of scholarship has generated valuable knowledge about material flows and production systems, but it often treats citizens and communities as consumers who must adopt predetermined circular behaviors. The active role of communities as creators of locally grounded circular solutions remains comparatively underdeveloped. Grassroots initiatives are sometimes presented as small-scale illustrations of circularity without sufficient analysis of their organizational processes, social relationships, and institutional environments. This technological and business-centered orientation leaves an important conceptual gap concerning the social foundations of circular transformation.

Research on social innovation provides stronger attention to citizen agency, collective learning, local experimentation, and community empowerment. Studies in this field frequently examine how grassroots actors respond to unmet social needs through alternative practices and collaborative networks. Social capital is commonly identified as an important resource for mobilization, trust-building, information exchange, and collective action. Significant limitations remain because social capital is often treated as uniformly beneficial. Less attention is given to its possible negative consequences, including social closure, exclusion, dependence on dominant local actors, resistance to external knowledge, and unequal participation. Limited differentiation among bonding, bridging, and linking social capital also makes it difficult to explain how community initiatives connect internal solidarity with broader institutional support.

Governance scholarship has examined collaborative governance, participatory planning, network governance, and multi-level environmental policy, yet these discussions are not consistently integrated with grassroots circular economy research. Governance is frequently measured through formal policies, institutional support, or stakeholder participation without examining how these arrangements interact with community relationships and informal practices. Empirical studies rarely investigate how social capital influences access to governance structures or how governance interventions transform existing community networks. Comparative and process-oriented evidence is especially limited regarding the evolution of these interactions over time. This study addresses these gaps by connecting circular economy, grassroots social innovation, social capital, and governance within a single relational framework.

The principal novelty of this study lies in its integrated assessment of social capital and governance as mutually constitutive dimensions of grassroots circular economy transitions. Social capital will not be positioned merely as a community resource, while governance will not be viewed simply as an external institutional condition. The analysis will examine how trust and networks shape governance participation, how institutional arrangements alter community relationships, and how their interaction affects initiative outcomes. This relational perspective provides a more nuanced explanation than approaches that assess community capacity and policy support independently. The study also recognizes that the same social or governance configuration may generate both enabling and constraining effects depending on local context, power relations, and stages of organizational development.

A further contribution concerns the multidimensional assessment of grassroots initiative performance. Environmental achievements such as waste reduction, material recovery, reuse, and resource efficiency will be examined alongside social outcomes such as inclusion, empowerment, skills development, livelihood creation, and community cohesion. Institutional outcomes, including legitimacy, policy influence, organizational resilience, and capacity for collaboration, will also form part of the analytical framework. This broader assessment avoids

reducing grassroots circular innovation to measurable waste-management outputs alone. The approach highlights the possibility that community initiatives may contribute to circular transitions by changing social norms, building collective capabilities, and creating new relationships between citizens and institutions.

The importance of this research is supported by the growing need for circular economy policies that are socially inclusive, context-sensitive, and institutionally feasible. Government programs that overlook local networks may fail to mobilize sustained participation, while community projects without supportive governance may struggle to move beyond isolated experimentation. Evidence concerning the interplay between social capital and governance can assist policymakers in designing funding schemes, partnership models, regulatory mechanisms, and capacity-building programs that respond to actual community conditions. Community organizations may use the findings to strengthen internal accountability and external collaboration without sacrificing local autonomy. Academic scholarship will benefit from a framework that connects material circularity with social relations and institutional power, positioning grassroots innovation as a substantive component of systemic circular economy transformation rather than a peripheral form of environmental activism.

## RESEARCH METHOD

### *Research Design*

This study employed a mixed-methods research design with a multiple-case study approach to examine the interplay between social capital and governance in community-led circular economy initiatives. The design combined quantitative survey data with qualitative evidence obtained through interviews, observations, and document analysis. A mixed-methods approach was considered appropriate because social capital and governance represent multidimensional phenomena that cannot be adequately understood through numerical measurement or narrative interpretation alone (del Río Castro et al., 2026; Loconto et al., 2026). Quantitative data were used to assess patterns of trust, reciprocity, participation, institutional support, accountability, and initiative performance, while qualitative data were used to explain how these factors were formed, negotiated, and experienced within specific community contexts.

The study adopted a convergent parallel strategy in which quantitative and qualitative data were collected during the same research period, analyzed separately, and integrated during the interpretation stage. This strategy enabled the researchers to compare statistical patterns with the experiences and explanations provided by community members, initiative coordinators, government representatives, and partner organizations. Areas of convergence were treated as evidence of consistent findings, while differences between the two data sources were examined to identify contextual variations, institutional tensions, or unequal perceptions among stakeholders. The integration process was intended to produce a comprehensive explanation of how social relationships and governance arrangements jointly influenced the continuity and effectiveness of grassroots circular economy practices.

The multiple-case study approach involved the examination of several community-led initiatives operating in different social and institutional environments. Each initiative was treated as an individual case with its own organizational structure, community characteristics, governance relationships, and circular economy activities. Cross-case analysis was subsequently conducted to identify recurring patterns and meaningful differences among the selected initiatives (Chawla & Kumar, 2026; Yeter et al., 2026). This design allowed the study to move beyond the description of a single local program and assess whether particular combinations of bonding, bridging, and linking social capital were associated with specific governance models and initiative outcomes.

The analytical framework positioned social capital as the main social dimension and governance as the principal institutional dimension. Social capital was examined through trust, shared norms, reciprocity, collective identity, internal networks, intercommunity relationships, and connections with external institutions. Governance was assessed through participation in decision-making, transparency, accountability, leadership distribution, institutional coordination, access to public resources, policy recognition, and conflict-resolution mechanisms. Initiative performance was evaluated through organizational continuity, member participation, material recovery, resource reuse, social inclusion, community empowerment, and capacity for replication or expansion.

### *Research Target/Subject*

The study population consisted of individuals and organizations involved in community-led circular economy initiatives within the selected research areas. The target population included community members, volunteers, initiative coordinators, local leaders, representatives of local government agencies, nongovernmental organizations, social enterprises, waste-management actors, and other institutional partners. Eligible initiatives included community waste banks, neighborhood recycling programs, repair and reuse groups, community composting projects, upcycling enterprises, sharing networks, and locally managed resource-recovery programs. An initiative was considered eligible when it had operated for at least one year, involved active community participation, and implemented activities related to waste prevention, reuse, repair, recycling, composting, or resource sharing.

A purposive sampling technique was used to select twelve community-led initiatives that represented variation in organizational age, operational scale, geographical setting, governance support, and type of circular economy activity. Maximum variation was considered important because the study sought to understand how the relationship between social capital and governance differed across institutional and community contexts. The selection process also considered the availability of organizational records, willingness to participate, and the presence of interactions between community actors and external institutions. Initiatives that functioned solely as government-administered programs without meaningful community decision-making were excluded because they did not meet the criteria for grassroots social innovation.

The quantitative sample comprised 240 respondents, with approximately twenty participants recruited from each selected initiative. Respondents were required to be at least eighteen years old and to have participated in the initiative for a minimum of six months. Proportional consideration was given to gender, age, duration of participation, organizational role, and level of involvement to avoid overrepresenting initiative leaders or highly active members. Participants were selected from membership lists and activity records provided by each initiative, followed by systematic or simple random selection whenever reliable lists were available. Purposive recruitment was applied in initiatives that did not maintain complete membership records.

The qualitative sample included thirty-six key informants selected through purposive and criterion-based sampling. The informants consisted of twelve initiative coordinators, twelve active community members or volunteers, six local government representatives, and six representatives of partner organizations or social enterprises. Selection was based on knowledge of the initiative, involvement in decision-making, experience in managing partnerships, and familiarity with organizational challenges. Data collection continued until thematic saturation was reached, indicated by the recurrence of major explanations and the absence of substantially new information concerning social capital, governance practices, and initiative sustainability.

### *Research Procedure*

Quantitative data were collected through a structured questionnaire developed from established concepts of social capital, collaborative governance, and community-based circular economy performance. The questionnaire consisted of five sections covering respondent characteristics, social capital, governance quality, community participation, and initiative outcomes. Social capital was measured through items related to interpersonal trust, institutional trust, reciprocity, shared values, collective identity, internal cooperation, external networking, and access to influential institutions. Governance was measured through stakeholder involvement, transparency, accountability, leadership inclusiveness, institutional responsiveness, resource accessibility, policy support, and coordination among participating organizations.

Questionnaire items were assessed using a five-point Likert scale ranging from 1, representing strongly disagree, to 5, representing strongly agree. Initiative outcomes were measured through perceived organizational resilience, continuity of participation, environmental contribution, social inclusion, economic opportunities, knowledge development, and capacity for scaling. Several negatively worded statements were included to reduce acquiescence bias and encourage careful responses. Demographic and participation-related questions were included to examine whether perceptions differed according to age, gender, education, organizational role, length of involvement, and frequency of participation.

Instrument validity was evaluated through expert review and pilot testing. Three experts in circular economy studies, community development, and public governance assessed the relevance, clarity, and conceptual alignment of the questionnaire items. Revisions were made to eliminate ambiguous terms, reduce overlapping statements, and improve contextual suitability. The revised instrument was pilot-tested with thirty participants from community initiatives that were not included in the main sample. Construct validity was assessed through exploratory factor analysis, while internal consistency was examined using Cronbach's alpha. A coefficient of at least 0.70 was considered acceptable for each measurement dimension.

Qualitative data were collected using a semi-structured interview guide, a nonparticipant observation sheet, and a document-review protocol. The interview guide explored the history of each initiative, patterns of trust and cooperation, leadership arrangements, decision-making processes, relationships with government agencies, access to funding, conflict management, community inclusion, and perceived achievements. Flexible probing questions were used to clarify experiences and identify differences between formal institutional procedures and actual practices. The observation sheet recorded participation patterns, meeting dynamics, distribution of responsibilities, interaction among stakeholders, use of infrastructure, and evidence of circular economy activities.

The document-review protocol was used to examine meeting minutes, organizational regulations, partnership agreements, financial reports, membership records, government policy documents, activity reports, promotional materials, and waste- or resource-management records. Documentary evidence provided information about formal governance structures and allowed researchers to verify statements made during interviews. Data triangulation was strengthened by comparing survey responses, interview narratives, observed practices, and organizational documentation. Field notes and reflective memos were maintained throughout the research process to record contextual information and support analytical transparency.

### *Instruments, and Data Collection Techniques*

The research procedure began with the identification and mapping of community-led circular economy initiatives in the selected areas. Information was obtained from local government agencies, community networks, environmental organizations, social enterprises, and publicly available program records. Potential cases were screened according to the inclusion criteria, followed by preliminary communication with initiative coordinators. Formal

permission was obtained from each participating organization before participant recruitment and data collection began.

Ethical approval was obtained from the relevant institutional research ethics committee. All participants received an information sheet explaining the purpose of the study, voluntary participation, research procedures, potential risks, confidentiality protections, and the intended use of the data. Written informed consent was obtained before questionnaires or interviews were administered. Participants were informed that they could decline to answer particular questions or withdraw from the research without any negative consequences. Personal names and identifiable organizational information were replaced with codes or pseudonyms during transcription, analysis, and reporting.

Survey data were collected through printed questionnaires and secure online forms, depending on participants' technological access and preferences. Trained research assistants provided neutral explanations when respondents required clarification, without directing their answers. Completed questionnaires were checked for missing responses and response-pattern irregularities before data entry. Descriptive statistics were used to summarize respondent characteristics and the distribution of social capital, governance, participation, and initiative-performance scores. Reliability testing, correlation analysis, multiple regression, and interaction analysis were conducted to assess the relationships among the principal variables.

### *Data Analysis Technique*

The interaction analysis examined whether governance quality strengthened or weakened the relationship between social capital and initiative performance. Separate analyses were also conducted for bonding, bridging, and linking social capital because each dimension was expected to influence community initiatives differently. Control variables included organizational age, initiative size, respondent characteristics, type of circular activity, and level of government involvement. Statistical assumptions concerning normality, multicollinearity, heteroscedasticity, and independence of residuals were assessed before inferential results were interpreted. Statistical significance was determined at the 0.05 level, while effect sizes and confidence intervals were reported to support substantive interpretation.

Qualitative interviews were conducted face-to-face or through secure video-conferencing platforms and lasted approximately forty-five to seventy-five minutes. Interviews were audio-recorded with participant permission and transcribed verbatim. Observations were conducted during community meetings, recycling activities, training sessions, material-collection events, or other relevant organizational practices. Documentary materials were collected with institutional authorization and organized according to case, document type, and date.

Qualitative data were analyzed through thematic analysis. The process involved repeated reading of transcripts and field notes, initial coding, category development, theme construction, and comparison across cases. Deductive codes were derived from the research framework, including trust, reciprocity, participation, transparency, accountability, institutional support, power relations, and organizational resilience. Inductive codes were developed when participants introduced context-specific experiences that were not adequately represented by the initial framework. Peer debriefing, member checking, an audit trail, and comparison of multiple data sources were employed to strengthen credibility and dependability.

Quantitative and qualitative findings were integrated through joint displays and narrative comparison. Statistical relationships were compared with interview explanations, observed interactions, and documentary evidence from each initiative. Convergent findings were used to establish consistent patterns, while divergent findings were interpreted in relation to organizational history, local culture, stakeholder power, and institutional conditions. Cross-case synthesis was conducted to identify governance and social-capital configurations associated with stronger or weaker initiative outcomes. The final interpretation emphasized the

mechanisms through which community relationships and governance arrangements enabled, constrained, or transformed grassroots contributions to circular economy transitions.

## RESULTS AND DISCUSSION

Administrative records from the twelve selected community-led circular economy initiatives indicated substantial variation in organizational age, membership size, activity frequency, and institutional connectivity. The initiatives had operated for an average of 4.4 years, with organizational ages ranging from two to eight years. Community waste banks represented the largest category, followed by composting initiatives, repair and reuse groups, upcycling enterprises, and a community-sharing network. The twelve initiatives collectively involved 876 active community members and conducted 572 circular economy activities during the twelve-month observation period. These activities included waste collection, compost production, repair workshops, product-sharing events, recycling education, upcycling training, and community environmental campaigns.

Table 1. Operational Characteristics of the Selected Community-Led Circular Economy Initiatives

| Type of Initiative | Number of Initiatives | Mean Organizational Age (Years) | Survey Respondents | Active Community Members | External Partnerships | Annual Activities |
|---|---|---|---|---|---|---|
| Community waste banks | 4 | 5.8 | 80 | 362 | 11 | 214 |
| Community composting groups | 3 | 4.3 | 60 | 188 | 7 | 132 |
| Repair and reuse initiatives | 2 | 3.5 | 40 | 116 | 6 | 96 |
| Upcycling social enterprises | 2 | 4.0 | 40 | 132 | 5 | 88 |
| Community-sharing network | 1 | 2.0 | 20 | 78 | 3 | 42 |
| Total | 12 | 4.4 | 240 | 876 | 32 | 572 |

Secondary documentation showed that mature initiatives generally maintained more extensive partnerships and implemented activities more frequently than recently established organizations. The four community waste banks accounted for 37.4% of all recorded activities and maintained eleven partnerships with local governments, educational institutions, recycling businesses, and civil society organizations. The community-sharing network had the shortest operational history and the smallest number of formal partnerships, although its membership level remained relatively substantial. Documentary evidence also revealed that nine initiatives possessed written organizational rules, eight maintained regular financial records, seven had formal cooperation agreements, and only five produced annual performance reports. These findings demonstrate that grassroots initiatives were active at the community level, but their levels of organizational formalization and institutional support remained uneven.

The concentration of activities within community waste banks can be explained by their relatively established operational systems and stronger integration with municipal waste-

management programs. Waste banks generally possessed clearer procedures for membership registration, material collection, waste valuation, financial recording, and collaboration with recycling businesses. Their activities could be scheduled routinely because participants were familiar with the mechanisms of waste sorting and exchange. Composting, repair, reuse, and sharing initiatives depended more heavily on volunteer availability, specialized knowledge, suitable infrastructure, and irregular community demand. Organizational age appeared to provide initiatives with opportunities to develop routines, establish legitimacy, and build relationships with external stakeholders.

Differences in institutional documentation reflected contrasting levels of governance maturity. Initiatives with written rules, financial records, partnership agreements, and annual reports tended to demonstrate clearer divisions of responsibility and more predictable resource access. Informally managed initiatives relied primarily on interpersonal trust and verbal agreements, which facilitated flexibility but created vulnerability when coordinators became inactive or external funding ended. Formalization did not automatically produce superior participation because several highly structured initiatives reported declining volunteer involvement. The data suggest that organizational procedures contributed to continuity when they were supported by trust, inclusive leadership, and community ownership rather than imposed as purely administrative requirements.

Respondent-level descriptive statistics indicated generally positive perceptions of social capital, governance, participation, and initiative performance. Bonding social capital obtained the highest mean score at 3.93, indicating strong trust, reciprocity, and solidarity among members within the same initiative. Bridging social capital reached a mean of 3.71, while linking social capital recorded a lower mean of 3.49. The difference suggests that community members had stronger relationships with fellow participants than with government officials, funding institutions, businesses, or other actors possessing greater authority and resources. Overall social capital reached a mean score of 3.71, representing a moderately high level of relational capacity.

**Table 2.** Descriptive Statistics for the Principal Research Variables

| Variable | Mean | Standard Deviation | Minimum | Maximum | Respondents in High Category (%) |
|---|---|---|---|---|---|
| Bonding social capital | 3.93 | 0.57 | 2.20 | 5.00 | 67.5 |
| Bridging social capital | 3.71 | 0.63 | 1.80 | 5.00 | 56.7 |
| Linking social capital | 3.49 | 0.68 | 1.60 | 5.00 | 43.8 |
| Overall social capital | 3.71 | 0.52 | 2.05 | 4.95 | 57.9 |
| Participatory governance | 3.76 | 0.61 | 1.75 | 5.00 | 59.2 |
| Transparency and accountability | 3.58 | 0.66 | 1.50 | 5.00 | 48.3 |
| Institutional coordination | 3.42 | 0.71 | 1.25 | 5.00 | 41.7 |
| Policy and resource support | 3.36 | 0.74 | 1.20 | 5.00 | 38.8 |
| Overall governance quality | 3.53 | 0.58 | 1.60 | 4.90 | 46.7 |
| Community participation | 3.82 | 0.56 | 2.05 | 5.00 | 62.1 |

| | | | | | |
|---|---|---|---|---|---|
| Organizational resilience | 3.68 | 0.61 | 1.75 | 5.00 | 53.8 |
| Circular economy outcomes | 3.74 | 0.60 | 1.80 | 5.00 | 57.1 |
| Social inclusion and empowerment | 3.63 | 0.64 | 1.50 | 5.00 | 50.4 |
| Overall initiative performance | 3.69 | 0.54 | 1.85 | 4.95 | 55.8 |

Governance quality received a lower overall mean score of 3.53 compared with social capital and community participation. Participatory governance represented the strongest governance dimension, whereas policy and resource support received the lowest mean score. Respondents generally perceived that they were permitted to express opinions during meetings, but they reported weaker access to public funding, technical assistance, legal recognition, infrastructure, and long-term policy support. Initiative performance reached a mean score of 3.69, with circular economy outcomes rated slightly higher than social inclusion and empowerment. The result indicates that the initiatives were relatively successful in managing waste, reusing materials, and promoting circular practices, although their capacity to distribute benefits equitably and involve marginalized residents remained less consistent.

Pearson correlation analysis showed statistically significant positive associations among social capital, governance quality, community participation, and initiative performance. Overall social capital was positively related to initiative performance, ($r = .58$), ($p < .001$), while governance quality demonstrated a stronger correlation with performance, ($r = .63$), ($p < .001$). Community participation had the strongest direct relationship with initiative performance, ($r = .67$), ($p < .001$). Social capital was also positively associated with governance quality, suggesting that initiatives characterized by trust and cooperative networks were more likely to develop participatory and accountable governance practices.

**Table 3.** Correlations Among Social Capital, Governance, Participation, and Initiative Performance

| Variable | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. Social capital | 1.00 | | | |
| 2. Governance quality | .48*** | 1.00 | | |
| 3. Community participation | .62*** | .55*** | 1.00 | |
| 4. Initiative performance | .58*** | .63*** | .67*** | 1.00 |

*Note. N = 240. **p < .001.

Hierarchical multiple regression analysis was conducted to assess the predictive contribution of social capital, governance quality, and their interaction. Organizational age, initiative size, type of circular activity, respondent age, education, and length of participation were entered as control variables in the first model. The control variables explained 14% of the variance in initiative performance. The inclusion of social capital and governance quality increased the explained variance to 52%. The interaction term between social capital and governance quality produced a statistically significant increase of four percentage points, resulting in a final (R^2) of .56. Diagnostic testing produced variance inflation factor values between 1.18 and 2.07, indicating that multicollinearity did not threaten the regression estimates.

**Table 4.** Hierarchical Regression Predicting Community-Led Initiative Performance

| Predictor | Standardized Beta | Standard Error | t | p |
|---|---|---|---|---|
| Organizational age | .11 | .024 | 2.09 | .038 |
| Initiative size | .07 | .001 | 1.41 | .160 |
| Length of respondent participation | .09 | .018 | 1.87 | .063 |
| Social capital | .31 | .052 | 5.94 | <.001 |

| | | | | |
|---|---|---|---|---|
| Governance quality | .36 | .049 | 7.12 | <.001 |
| Social capital × governance quality | .18 | .041 | .16 | .002 |

Note. Final model: (R^2 = .56), adjusted (R^2 = .54), (F(9,230) = 32.54), (p < .001).

The strongest dimension-level predictors of initiative performance were linking social capital and institutional governance. Linking social capital, which represented connections with government agencies, universities, businesses, donors, and professional organizations, showed a stronger association with performance than bonding social capital. Bonding relationships remained important for maintaining internal commitment, but they were less effective in securing equipment, market access, regulatory support, training, or funding. Bridging social capital also contributed positively because connections across neighborhoods and social groups expanded volunteer recruitment, information exchange, and access to new ideas.

Simple-slope analysis clarified the significant interaction between social capital and governance quality. The relationship between social capital and initiative performance was strong under high-governance conditions, (B = .61), (p < .001), but weaker under low-governance conditions, (B = .28), (p = .019). Community trust and cooperation generated stronger outcomes when initiatives also possessed transparent decision-making, accountable leadership, stable partnerships, and institutional responsiveness. High social capital did not fully compensate for weak governance because informal solidarity could not consistently resolve funding shortages, leadership concentration, unclear authority, or administrative barriers. Strong governance also produced limited results when members lacked trust and commitment, indicating that social and institutional capacities functioned as complementary rather than interchangeable resources.

Qualitative data from thirty-six key informants and observations across the twelve initiatives produced five recurring themes: internal trust, shared environmental values, inclusive decision-making, external institutional brokerage, and organizational adaptability. Internal trust appeared in interviews from all twelve initiatives, while effective external brokerage was evident in only eight cases. Inclusive decision-making was consistently observed in nine initiatives, although three cases remained dominated by founders or senior leaders. Bureaucratic barriers were reported in seven initiatives, particularly in relation to funding applications, legal registration, public facility use, and cooperation with municipal agencies.

**Table 5.** Cross-Case Profiles of Representative Community-Led Initiatives

| Case | Initiative Type | Social Capital Profile | Governance Arrangement | Main Strength | Main Constraint | Performance Level |
|---|---|---|---|---|---|---|
| Case A | Community waste bank | High bonding, moderate bridging, high linking | Collaborative and formally structured | Stable government and recycling-sector partnerships | Dependence on commodity prices | High |
| Case B | Repair and reuse collective | Moderate bonding, high bridging, moderate linking | Participatory but informally organized | Strong knowledge exchange and youth participation | Limited permanent facilities | Moderate to high |
| Case | Neighborhoo | High | Leader- | Strong | Weak | Moderate |

| | | | | | | |
|---|---|---|---|---|---|---|
| C | d composting group | bonding, low bridging, low linking | centered and minimally formalized | neighborhood solidarity | external support and leadership succession | |
| Case D | Women-led upcycling cooperative | High bonding, high bridging, high linking | Hybrid cooperative governance | Income generation and strong institutional networks | Unequal workload among members | High |

Representative case profiles demonstrated that similar levels of internal trust did not necessarily produce equivalent outcomes. Case A and Case C both exhibited high bonding social capital, yet Case A achieved stronger continuity because it maintained formal agreements with public agencies and recycling businesses. Case C depended primarily on one neighborhood leader and had limited access to external knowledge and financial resources. Case B possessed weaker internal cohesion but benefited from diverse networks involving students, technicians, artists, and environmental activists. Case D combined close interpersonal relationships with broad networks and formal cooperative procedures, resulting in stronger market access, training opportunities, and livelihood benefits.

Interview narratives indicated that trust reduced the perceived risks of participating in collective environmental activities. Members were more willing to separate household waste, share equipment, volunteer time, and contribute small amounts of money when they believed that coordinators managed resources responsibly. Shared environmental values also strengthened collective identity by framing circular practices as community responsibilities rather than individual lifestyle choices. Trust became less effective when financial information was unclear or when decisions were made by a small group. Several informants explained that members gradually withdrew from activities when they felt their contributions were not recognized or when benefits were distributed unevenly.

Cross-case comparison showed that external relationships were most beneficial when community actors retained meaningful influence over program priorities. Government assistance improved performance when it provided infrastructure, technical training, legal recognition, or access to recycling markets without replacing community decision-making. Institutional involvement created tension when public agencies introduced predetermined targets or reporting requirements that did not reflect local capacities. Several coordinators described short-term project funding as useful but unstable because activities often declined after the funding period ended. Initiatives with diversified partnerships were more resilient because they did not depend on a single government agency, donor, business, or community leader.

The integrated findings indicate that grassroots social innovation for circular economy transitions is shaped by the combined quality of community relationships and governance arrangements. Social capital supported mobilization, trust, knowledge sharing, and collective commitment, while governance provided institutional clarity, accountability, coordination, and access to external resources. Neither dimension was independently sufficient to ensure sustained performance. Dense internal networks could become socially closed or dependent on particular leaders, while formal governance structures could become bureaucratic and disconnected from community motivations.

The findings also suggest that linking and bridging relationships are especially important for moving initiatives beyond localized environmental action. Bonding social capital helped communities initiate activities, but external networks enabled them to access technology, markets, funding, policy recognition, and specialized expertise. Circular economy transitions at

the grassroots level should therefore not be interpreted merely as the aggregation of individual recycling behaviors. Their transformative potential depends on whether community initiatives can maintain local trust, develop inclusive governance, and establish equitable relationships with institutions capable of supporting broader structural change.

The findings demonstrate that community-led circular economy initiatives were supported by moderately high levels of social capital, community participation, and perceived organizational performance. Bonding social capital emerged as the strongest social-capital dimension, indicating that interpersonal trust, reciprocity, shared environmental values, and collective identity were well established within the participating communities. Bridging social capital was also relatively strong, although its distribution varied across initiative types. Linking social capital received the lowest mean score, showing that relationships between grassroots actors and institutions possessing greater authority, expertise, or financial resources remained less developed than relationships within the communities themselves. This pattern suggests that grassroots initiatives were socially embedded but not equally connected to the institutional systems required to consolidate and expand their activities.

Governance quality was positively evaluated but remained weaker than internal social cohesion and community participation. Participatory decision-making represented the strongest governance dimension because most members perceived that they could express their opinions and contribute to organizational activities. Institutional coordination, policy recognition, resource accessibility, transparency, and accountability showed less consistent results across the twelve cases. Several initiatives possessed written organizational rules and financial records, but fewer maintained formal partnership agreements, annual performance reports, or long-term arrangements with public institutions. The findings indicate that governance was present within the initiatives, although its quality depended on leadership practices, organizational maturity, and the availability of supportive external actors.

Inferential analysis revealed that social capital and governance quality were significantly associated with initiative performance. Community participation showed the strongest bivariate relationship with organizational resilience, circular economy outcomes, and social inclusion. Governance quality produced a slightly stronger direct contribution to initiative performance than overall social capital in the multivariate model. The interaction between social capital and governance was also statistically significant, showing that the benefits of trust and community networks became more substantial when they were accompanied by transparent, participatory, and coordinated governance. Social cohesion alone was unable to compensate fully for weak institutional support, concentrated leadership, unclear responsibilities, or unstable access to resources.

Case-study evidence clarified the mechanisms underlying these statistical relationships. Initiatives combining strong internal trust, diverse external networks, inclusive leadership, and formal institutional partnerships demonstrated the highest levels of continuity and perceived impact. Initiatives relying predominantly on bonding relationships remained capable of organizing local activities but were more vulnerable to leadership succession problems, volunteer fatigue, facility limitations, and financial uncertainty. External support produced positive outcomes when it expanded community capacity without replacing local decision-making. Institutional intervention became less productive when public agencies imposed administrative requirements or targets that were poorly aligned with community priorities and operational capabilities.

The strong contribution of internal trust and collective identity is consistent with the broader social-capital literature, which associates social relationships with information sharing, norm formation, and coordinated environmental action. The findings also support the foundational argument that grassroots innovation develops through networks of community actors who generate locally relevant responses to sustainability problems that are insufficiently addressed by markets or formal institutions. Seyfang and Smith describe grassroots innovations

as bottom-up forms of experimentation embedded in civil society and shaped by social needs, values, and local contexts. The present study extends this perspective by showing that the existence of grassroots networks does not automatically ensure organizational continuity unless community relationships are connected to effective governance arrangements.

The importance of place-specific social conditions corresponds with the findings of Purvis et al. (2025), whose study of a community repair initiative showed that grassroots circular practices evolve in response to local material conditions and social challenges. Their analysis emphasized that community repair can address waste-related problems while simultaneously responding to unemployment, deprivation, and limited access to services. The present findings similarly show that community-led circularity generates outcomes extending beyond material recovery. Social inclusion, practical learning, livelihood opportunities, environmental awareness, and community cohesion were repeatedly identified as important dimensions of initiative performance. Circular economy transitions at the grassroots level should therefore be understood as socio-material processes rather than technical efforts to increase recycling rates alone.

The significant role of linking social capital and multi-actor coordination is also consistent with research on polycentric waste governance. Istiyani and Handayani (2022) found that community-based waste banks could strengthen circular economy practices by developing relationships across governmental, civil-society, and community levels. Their study positioned civil-society organizations as important actors in balancing authority and connecting top-down programs with bottom-up initiatives. The present study reaches a comparable conclusion but adds an important qualification: external partnerships were beneficial only when communities retained meaningful decision-making authority. Institutional connectivity was not inherently empowering because partnership arrangements could also increase administrative burdens, reinforce dependence, or transfer control to better-resourced actors.

The multidimensional outcomes identified in this research correspond with recent scholarship that challenges technocentric and industry-dominated interpretations of the circular economy. Research on grassroots circularity in Bologna found that community initiatives integrated material reuse with solidarity, reciprocity, care, social equity, and territorial well-being, while simultaneously confronting fragmented governance and insufficient institutional recognition. Miranda de Souza et al. (2026) similarly conceptualized community-oriented reuse organizations as actors that connect product recovery with education, inclusion, and ecological care. The present findings reinforce these arguments by demonstrating that social value is not merely an incidental benefit of circular practice. Social relationships, collective capabilities, and institutional participation constitute part of the infrastructure through which circularity is produced.

The prominence of bonding social capital signifies that grassroots circular economy initiatives remain deeply dependent on close interpersonal relationships. Trust reduces uncertainty when participants contribute labor, share tools, sort waste, manage collective funds, or accept responsibilities without immediate financial rewards. This dependence represents both an organizational asset and a structural vulnerability. Close relationships can mobilize participation rapidly, but they may also restrict recruitment, discourage criticism, and concentrate informal authority among founders or long-standing members. High bonding social capital should consequently not be interpreted as unequivocal evidence of institutional strength.

The lower level of linking social capital signifies an incomplete connection between community innovation and the broader structures governing resources, markets, infrastructure, and public policy. Grassroots actors may demonstrate creativity and commitment while remaining peripheral to formal planning and budgeting processes. Such marginality can leave initiatives responsible for producing public environmental benefits without receiving stable institutional recognition or adequate material support. Community resilience may conceal this imbalance because volunteer labor and interpersonal solidarity allow activities to continue

despite structural deficiencies. Apparent grassroots success may therefore coexist with the transfer of environmental responsibilities from public institutions to unpaid or underpaid community actors.

The significant interaction between social capital and governance signifies that the relationship between community capacity and institutional quality is configurational rather than additive. Strong communities do not merely contribute one set of resources while governments provide another independent set. Governance rules shape whose relationships are recognized, whose knowledge influences decisions, and which community practices receive funding or legal legitimacy. Social networks simultaneously affect who can access decision-making arenas, negotiate partnerships, and hold leaders accountable. The effectiveness of each dimension is consequently conditioned by the other, making it misleading to evaluate social capital and governance as isolated predictors.

The variation among the case studies signifies that no single organizational model can guarantee successful grassroots circularity. Formalization benefited several initiatives by clarifying responsibilities and improving financial accountability, but excessive formalization could weaken flexibility and discourage volunteer participation. Government involvement increased access to facilities and expertise, but dominant public intervention could undermine community ownership. Informal cooperation created adaptive spaces for experimentation, but it often failed to protect initiatives from leadership turnover and resource shortages. Institutional development should therefore be understood as a balancing process rather than a linear movement from informal community action toward increasingly bureaucratic organization.

The theoretical implication of the findings concerns the need to reposition social capital within circular economy scholarship. Social capital should not be treated merely as a contextual variable that facilitates the implementation of technically designed circular programs. Trust, reciprocity, collective identity, and networks constitute productive resources that influence how materials are collected, valued, repaired, exchanged, and returned to use. Social relationships form part of the operational architecture of circularity because they determine whether community members are willing to alter routines, share responsibilities, and sustain collective practices. Circular economy frameworks that exclude these relational processes provide an incomplete explanation of how local transitions occur.

The governance implication concerns the inadequacy of policies based solely on grants, technical training, or short-term environmental targets. Material support can assist grassroots initiatives, but its effects are likely to remain temporary when decision-making authority, institutional coordination, and community accountability are neglected. Public institutions need to recognize communities as co-producers of circular systems rather than as beneficiaries or implementation agents for predetermined programs. Meaningful recognition requires opportunities to shape program objectives, define contextually relevant indicators, negotiate administrative requirements, and participate in evaluating results.

The managerial implication concerns the need for community organizations to balance relational trust with transparent procedures. Informal trust may be sufficient during the formation of an initiative, but organizational growth increases the need for financial documentation, role clarification, conflict-resolution mechanisms, succession planning, and equitable workload distribution. Formal procedures should protect community values rather than replace them. Participatory budgeting, rotating leadership, accessible meeting records, regular member consultations, and publicly agreed criteria for distributing benefits may strengthen accountability without eliminating the flexibility that characterizes grassroots innovation.

The social implication concerns the possibility that circular economy initiatives may reproduce exclusion even when they pursue environmentally progressive goals. Participation often depends on available time, mobility, digital access, technical knowledge, and confidence in public meetings. Residents with care responsibilities, unstable employment, disabilities,

limited literacy, or weak connections to community leaders may face barriers to involvement. Strong average participation scores can conceal unequal influence among members. Inclusive circular transitions require attention not only to the number of participants but also to whose knowledge is heard, whose labor is relied upon, and who obtains environmental, social, and economic benefits.

The high level of bonding social capital can be explained by the locally embedded nature of the selected initiatives. Community waste banks, composting groups, repair collectives, upcycling enterprises, and sharing networks commonly develop through existing neighborhood relationships, shared environmental concerns, or repeated interaction among residents. Familiarity reduces the perceived risk of collective action and enables participants to coordinate without complex contractual arrangements. Shared experiences also make environmental problems visible in concrete forms, such as unmanaged household waste, limited disposal services, declining neighborhood cleanliness, or the loss of repair practices.

The weaker level of linking social capital can be explained by asymmetries between grassroots organizations and formal institutions. Government agencies, businesses, universities, and funding organizations operate through professional language, administrative schedules, legal procedures, and performance requirements that may be unfamiliar to community groups. Grassroots leaders may possess extensive local knowledge but limited experience in preparing proposals, negotiating agreements, documenting environmental outcomes, or accessing formal planning forums. Institutional actors may also prioritize initiatives that can demonstrate easily measurable material outputs, leaving socially valuable but less quantifiable activities underrecognized.

The stronger predictive role of governance quality can be explained by its influence on the conversion of community resources into sustained outcomes. Trust can motivate participation, but governance determines how responsibilities are allocated, how conflicts are managed, how resources are recorded, and how external partnerships are coordinated. Transparent and inclusive governance allows social capital to become organizational capacity rather than remain a collection of interpersonal relationships. Weak governance can dissipate community commitment through unclear decisions, unequal workloads, financial suspicion, or dependence on individual leaders.

The significant interaction effect can also be explained by reciprocal reinforcement. Effective governance increases trust when leaders communicate openly, distribute opportunities fairly, and respond to member concerns. High social capital improves governance when participants share information, attend meetings, monitor collective resources, and accept mutually agreed rules. This reciprocal process may produce a virtuous cycle in stronger initiatives and a negative cycle in weaker ones. Low trust discourages participation, limited participation reduces accountability, weak accountability increases suspicion, and growing suspicion further reduces collective commitment.

Future policy development should establish long-term support structures that connect grassroots initiatives with public agencies, markets, technical experts, and other communities. Municipal governments could create accessible circular economy forums in which community organizations participate in planning, budgeting, implementation, and evaluation. Simplified grant procedures, shared facilities, technical mentoring, legal assistance, and multi-year partnership arrangements would reduce the administrative disadvantages experienced by small initiatives. Institutional support should remain flexible enough to accommodate differences in organizational age, community capacity, and type of circular activity.

Community organizations should prioritize the development of bridging and linking relationships without weakening their local foundations. Partnerships with schools, universities, social enterprises, recycling companies, professional associations, and neighboring initiatives can broaden access to volunteers, knowledge, technology, and markets. Network expansion should be accompanied by safeguards protecting community ownership and

preventing external actors from controlling priorities. Written partnership principles, shared decision-making procedures, transparent resource commitments, and periodic partnership evaluations can help communities obtain external support while preserving autonomy.

Future research should use longitudinal and comparative designs to examine how social capital and governance change across different stages of initiative development. The cross-sectional associations identified in this study do not establish definitive causal direction because successful initiatives may generate stronger trust and better governance rather than merely result from them. Repeated measurement could determine whether governance improvements precede organizational resilience or emerge after initiatives become more established. Comparative research across urban and rural settings, institutional regimes, cultural environments, and circular economy sectors would also clarify which findings are context-specific and which represent broader patterns.

Future measurement should combine subjective perceptions with verified material, organizational, and distributional indicators. Survey respondents may evaluate initiatives positively because of emotional attachment, social desirability, or loyalty to community leaders. Waste diversion, material reuse, financial continuity, membership retention, leadership turnover, benefit distribution, and participation by underrepresented groups should be documented over time. Such evidence would provide a more rigorous basis for assessing whether grassroots initiatives generate temporary local improvements or contribute to wider circular economy transitions. The most important next step is not simply to scale individual projects, but to transform the institutional conditions that determine whether community innovation can remain autonomous, inclusive, and durable.

## CONCLUSION

The most important finding of this study is that grassroots social innovation contributes to circular economy transitions most effectively when strong social capital is supported by inclusive and responsive governance. Internal trust, reciprocity, and collective identity enabled communities to initiate and sustain circular practices, yet these relational resources alone were insufficient to secure long-term organizational resilience. Initiatives with stronger bridging and linking networks, transparent leadership, institutional coordination, and access to external resources demonstrated better environmental, social, and organizational outcomes. This finding distinguishes the study from approaches that treat social capital or governance as independent determinants of community performance, because the evidence indicates that their interaction is more influential than either factor operating separately.

The principal contribution of this research lies in its conceptual integration of social capital, governance, and grassroots circular economy performance within a single analytical framework. The study advances circular economy scholarship by positioning community relationships and institutional arrangements as central components of transition processes rather than as supporting contextual factors. Its methodological contribution is reflected in the combination of survey analysis, cross-case comparison, interviews, observations, and documentary evidence, which enabled statistical relationships to be interpreted alongside local experiences and organizational practices. This integrated approach provides a more comprehensive means of assessing how bonding, bridging, and linking social capital interact with participatory governance, accountability, institutional support, and community autonomy.

The limitations of this study arise from its cross-sectional design, reliance on participant perceptions, and concentration on a relatively limited number of community-led initiatives. The findings cannot establish definitive causal relationships, while self-reported assessments may be influenced by social desirability, loyalty to community leaders, or varying interpretations of initiative success. Differences in geographical context, organizational maturity, and circular activity also limit the broader generalization of the results. Future research should employ

longitudinal, comparative, and multi-level designs that incorporate objective indicators of material recovery, financial continuity, participation equality, institutional support, and organizational survival. Further investigation should also examine how power relations, digital platforms, gender, socioeconomic inequality, and local policy environments influence the capacity of grassroots initiatives to scale their impact without losing community ownership and social inclusiveness.

## DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s) used ChatGPT (OpenAI) to assist in drafting, refining, and improving the clarity and readability of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

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## AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

## DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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