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BONDING AND BRIDGING SOCIAL CAPITAL IN DIGITAL VILLAGE LIVELIHOOD STRATEGIES: EVIDENCE FROM KAUDITAN SATU VILLAGE, NORTH MINAHASA REGENCY, INDONESIA

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ABSTRACT

Rapid digital transformation in Indonesia has prompted rural communities to adopt smart village frameworks, yet the role of social capital particularly its bonding and bridging dimensions in shaping farmer livelihood strategies within digital environments remains underexplored. It remains unclear whether strong internal cohesion or expansive cross-group networks better support livelihood diversification under digitalization. This study aims to analyse the levels of bonding and bridging social capital among farmers and to assess their effects on livelihood strategy assets in Kauditan Satu Village, the first integrated digital village in North Minahasa Regency, North Sulawesi, Indonesia. A descriptive survey was conducted from March to November 2024 with 100 purposively selected farmer respondents. Data were collected through structured interviews and questionnaires, and analysed using Likert-scale scoring, Principal Component Analysis (PCA), multiple linear regression, and Structural Equation Modelling (SEM) to examine relationships between social capital dimensions and livelihood pentagon assets comprising natural, human, social, physical, and financial capital. Bonding social capital was classified as high (66.55%), while bridging social capital reached a moderate level (53.24%). Physical capital recorded the highest livelihood asset value (2.64), while financial capital was lowest (2.01), yielding a total pentagon score of 12.14. PCA confirmed strong construct validity (KMO = 0.780–0.904; $p < 0.001$). Regression analysis yielded $R^2 = 0.735$, though neither bonding ($\beta = -0.696$; $p = 0.065$) nor bridging ($\beta = -0.163$; $p = 0.663$) reached individual statistical significance. SEM results ($R^2 = 0.770$) revealed a strong negative total effect of bonding social capital (-0.956) and a positive but modest effect of bridging social capital ($+0.079$) on livelihood strategies. While bonding social capital is well-established, its excessive inward orientation may constrain openness to digital livelihood innovations. Bridging social capital, though moderate, demonstrates positive developmental potential. Strengthening cross-group digital networks is recommended as a priority intervention for sustainable livelihood development in digital villages.

KEYWORDS: social capital; livelihood strategies; farmers characteristics; digital village; farmer livelihood strategies; digitalizing government; kauditan satu; North Minahasa Regency

1. INTRODUCTION

The accelerating wave of digital transformation has fundamentally reshaped the governance and economic landscape of rural communities worldwide. In developing countries such as Indonesia, where the rural population constitutes a substantial share of the national workforce and where agriculture remains the backbone of local economies, the integration of information and communication technology (ICT) into village governance systems represents both a strategic opportunity and a formidable challenge [1]. The concept of the "digital village" (*desa digital*) defined as an administrative unit that integrates ICT into government services, community empowerment, and economic activities [2] has gained considerable traction in Indonesia as part of a broader national agenda to bridge the urban-rural digital divide [3]. The deployment of smart village frameworks has been shown to enhance public service delivery, broaden market access for smallholder producers, and strengthen rural communities' adaptive capacities [4]. However, the capacity of rural communities to translate digital infrastructure into genuine livelihood improvements is not determined by technology alone; it is deeply mediated by the social fabric of the community itself.

Social capital has long been recognised as a critical, yet often invisible, determinant of community well-being and economic resilience [5]. Defined broadly as the networks, norms of reciprocity, and trust that facilitate coordination and collective action among individuals and groups [6], social capital encompasses the relational infrastructure through which communities access information, mobilise resources, and navigate economic uncertainty [7]. Scholars have distinguished two principal forms of social capital bonding and bridging each with distinct functional properties. Bonding social capital refers to the dense, affective ties forged among individuals within homogeneous social groups, such as kinship networks, farming cooperatives, or village associations; these ties generate strong norms of mutual obligation and in-group solidarity [8]. Bridging social capital, by contrast, emerges from weaker, more heterogeneous connections that span across different social groups and external institutions, thereby facilitating the flow of novel information, broader market linkages, and exposure to new economic strategies [9]. In digital environments, these two dimensions of social

capital interact with ICT platforms in complex ways: bonding capital can amplify the cohesive strength of online farmer groups and support peer-to-peer knowledge exchange, while bridging capital has the potential to extend farmers' reach beyond their immediate social circle, connecting them with markets, extension services, and government programmes [10].

The empirical literature on social capital in agricultural settings underscores the nuanced and context-specific nature of its effects on livelihood outcomes. Studies conducted across Southeast Asian and Pacific communities have demonstrated that bonding social capital contributes positively to collective resource management, disaster resilience, and mutual insurance mechanisms among smallholder farmers [11]. Bridging social capital, meanwhile, has been associated with greater technology adoption, improved access to agricultural extension services, and enhanced food security in both urban and rural Indonesia [12]. In multi-level irrigation governance contexts, social capital has been identified as a critical factor in sustaining farmer participation and institutional cooperation [13]. However, the relationships between social capital and livelihoods are not uniformly positive; excessively strong in-group bonds may, paradoxically, constrain innovation and limit engagement with external markets, a phenomenon sometimes described as the "dark side" of social cohesion [14]. These divergent findings underline the importance of examining bonding and bridging social capital not as substitutes, but as complementary and sometimes competing forces that together shape the trajectory of rural livelihoods under conditions of digital transformation.

The Sustainable Livelihoods Framework (SLF), originally developed by Chambers and Conway and subsequently elaborated by the Department for International Development (DFID), provides a robust analytical structure for understanding how rural households mobilise diverse asset portfolios—comprising natural, human, social, physical, and financial capital to pursue livelihood strategies and achieve sustainable outcomes [15]. Within the SLF, social capital is not merely one asset among five; it operates as a cross-cutting enabler that mediates access to all other capitals [16]. Studies employing this framework in Indonesia and comparable developing contexts have demonstrated that the composition of the livelihood pentagon varies significantly across community

types, with physical capital tending to be stronger in well-connected peri-urban villages, while financial capital often represents the most critical bottleneck for smallholder households [17]. The integration of digital technologies into village governance systems has introduced new dimensions into the SLF, adding digital access and ICT literacy as emergent capitals that interact with existing livelihood assets and strategies [18]. Understanding how social capital particularly its bonding and bridging dimensions influences the distribution and utilisation of these pentagon assets in a digital village context is therefore of significant theoretical and practical importance.

Despite growing scholarly interest in both digital village development and social capital in agriculture, empirical studies that directly examine the relationship between bonding/bridging social capital and the livelihood pentagon assets of farmers in a declared digital village context remain scarce, particularly in the context of Eastern Indonesia [19]. *Kauditan Satu Village*, located in North Minahasa Regency, North Sulawesi, represents an ideal case for such investigation: it was the first village in the regency to be officially designated as an integrated digital village, providing a unique opportunity to observe how digital infrastructure interacts with pre-existing social capital endowments and livelihood configurations [20]. This study therefore aims to: (1) measure the levels of bonding and bridging social capital among farmers in *Kauditan Satu Village*; (2) characterize the livelihood asset pentagon of respondent farmers using the SLF; and (3) assess the effects of bonding and bridging social capital on livelihood strategies using PCA, multiple linear regression, and SEM. The findings are intended to inform evidence-based policy recommendations for strengthening social capital and livelihood resilience in Indonesia's expanding network of digital villages.

2. METODOLOGY

2.1. Study Area and Research Design

This study was conducted from March to November 2024 in *Kauditan Satu Village*, *Kauditan* Sub-district, North Minahasa Regency, North Sulawesi Province, Indonesia. The village is located approximately 30 km north of Manado City and covers an area of 11.37 km², encompassing approximately 227 ha of dry agricultural fields, 50 ha of irrigated rice paddies, 827 ha of smallholder plantations, and 34 ha of residential land. The village is Indonesia's first integrated digital village in North Minahasa Regency, and its total population in 2023 was 3,076 inhabitants. The dominant agricultural commodities include rice, chilli, tomatoes, pumpkins, melons, and watermelons. This study employed a descriptive survey design combining quantitative and qualitative approaches to capture both the extent of social capital and its relationship with livelihood strategies.

2.2. Sampling and Data Collection

The study population comprised all farmers residing and actively engaged in agricultural activities in *Kauditan Satu Village*. A sample of 100 respondents was selected using a purposive sampling technique, targeting farmers who met the criteria of active land cultivation and residence in the village for at least five years. Primary data were gathered through structured face-to-face interviews using a validated questionnaire developed on the basis of the theoretical frameworks of social capital (bonding and bridging dimensions) and the Sustainable Livelihoods Framework. Secondary data were obtained from the village administration, the Central Statistics Agency (BPS) of North Minahasa Regency, and relevant government agencies. Data collection encompassed farmer socio-demographic characteristics, internet access patterns, digital device ownership, bonding social capital indicators, bridging social capital indicators, and livelihood asset pentagon components, it can be seen in Table 1.

Table 1. Variable operationalization.

Variable	Indicator	Criteria
Farmer characteristics		
Education	Level of education attained in school	<ul style="list-style-type: none"> • Not in school yet • Elementary school graduate • Junior high school graduate • Graduated from senior high school / vocational school
Age	Farmer age	<ul style="list-style-type: none"> • 20-30 years • 30-40 years

		<ul style="list-style-type: none"> • 40-50 years • >50 years
Digital device ownership	4G device ownership, 5G device, computer/laptop/ personal computer, tablet	<ul style="list-style-type: none"> • Yes • No
Duration of internet access	Accessing social media, sending and receiving emails, online buying and selling	<ul style="list-style-type: none"> • <1 hours • 1-3 hours • 3-5 hours • >5 hours
Social capital		
Bonding	<ol style="list-style-type: none"> 1. I have confidence in some of my online friends, who can help me overcome my problems. 2. Seeking advice from my friends through online platforms, especially when it comes to making important decisions. 3. Sharing aspects of my personal life with friends online. 4. Through online interactions, I get information related to agriculture. 	<ul style="list-style-type: none"> • Very low • Low • Moderately • High • Very high
Bridging	<ol style="list-style-type: none"> 1. Communicating with individuals through online media helps me broaden my horizons to the world outside my village environment. 2. Interacting with others online sparks my interest in trying new experiences. 3. Engaging in online interactions makes me part of a wider farming community than the farming community in my village. 4. I spend time supporting the activities of the online communities in which I participate. 5. Interacting with individuals online encourages me to talk to new people every day. 	<ul style="list-style-type: none"> • Very low • Low • Moderately • High • Very high
Livelihood strategy		
Natural capital	Land tenure, land productivity, water availability, livestock ownership	<ul style="list-style-type: none"> • Good • Medium • Poor
Human capital	Education, health, experience, skills/skills	<ul style="list-style-type: none"> • Good • Medium • Poor
Social capital	Community organization, social network, mutual aid, participation	<ul style="list-style-type: none"> • Good • Medium • Poor
Financial capital	Income, expenses, savings, debt	<ul style="list-style-type: none"> • Good • Medium • Poor
Physical capital	Facilities, infrastructure, equipment, accessibility	<ul style="list-style-type: none"> • Good • Medium • Poor

2.3. Measurement of Variables

All primary variables were operationalised and measured using a five-point Likert scale (1 = Very Low to 5 = Very High). Bonding social capital was assessed through four indicators: mutual trust within the farming group, in-group norms of reciprocity, participation in community

organisations, and intensity of face-to-face interaction.

Bridging social capital was measured through five indicators: engagement with external institutions and agencies, use of digital networks for cross-group communication (Whats-app, Facebook, Instagram, Telegram), access to external agricultural

information, participation in inter-village or inter-group activities, and trust toward external actors. The livelihood pentagon was assessed through five capital dimensions: (a) Human Capital education level, health status, farming experience, and skills; (b) Natural Capital land tenure, land productivity, water availability, and livestock ownership; (c) Social Capital community organisation participation, social networks, mutual aid, and civic engagement; (d) Physical Capital facilities, infrastructure, working tools, and accessibility; (e) Financial Capital income, household expenditure, savings, and debt burden. Scale scoring followed the formula: Percentage Score = (Total Score / Maximum Score) × 100, with categories defined as: Very Low (0–19.99%), Low (20–39.99%), Moderate (40–59.99%), High (60–79.99%), and Very High (80–100%).

2.4. Data Analysis

Data were analysed in four sequential stages. First, descriptive statistics and Likert-scale percentage scoring were computed to characterise respondent profiles and social capital levels. Second, Principal Component Analysis (PCA) with Kaiser-Meyer-Olkin (KMO) sampling adequacy and Bartlett's Test of Sphericity was performed to validate the internal structure of the bonding, bridging, and livelihood constructs using SPSS 26.0. Third, multiple linear regression analysis was conducted to estimate the joint explanatory power (R^2) of bonding and bridging social capital on livelihood strategies, and to test the direction and significance of each predictor. Fourth, Structural Equation Modelling (SEM) was applied to examine the total effects of bonding and bridging social capital on livelihood strategies while accounting for

the full latent variable structure. Instrument validity was assessed by comparing item-level Pearson correlation values against the r-table threshold ($r = 0.195$; $n = 100$; $\alpha = 0.05$), and reliability was evaluated using Cronbach's Alpha (threshold ≥ 0.70).

3. RESULTS

3.1. Characteristics of the Study Area

Kauditan Satu Village is situated at an altitude of 214 meters above sea level with a tropical climate (24–34°C). Its topography comprises a combination of slopes and plains, making it suitable for diverse horticultural and food crop production. The village is administratively bounded to the west by Kawiley Village, to the north by Mount Klabat, to the east by *Kauditan II* Village, and to the south by Lansot Village, Kema Sub-district. The productive-age population (15–59 years) constitutes the largest demographic segment at 64.89%, providing an adequate labour supply for both on-farm and digital-economy activities. *Kauditan Satu* was officially designated as the first integrated digital village in North Minahasa Regency, with digital infrastructure managed through collaboration among the village government, the Ministry of Communication and Informatics (KOMINFO), and the Telecommunications and Information Accessibility Agency (BAKTI).

3.2. Respondent Characteristics

The following tables present the socio-demographic profile of the 100 farmer respondents, including age distribution, educational attainment, duration of daily internet use, and digital device ownership, can be seen in Table 2 - Table 4

Table 2. Distribution of farmer respondents by age group.

Age Group (Years)	Number of Respondents
20 - 30	19
31 - 40	27
41 - 50	36
> 50	18
Total	100

Table 3. Distribution of farmer respondents by educational level

Educational Level	Number of Respondents
Did not complete school	19
Elementary school graduate	21
Junior high school graduate	34
Senior high school / vocational school graduate	26
Total	100

Table 4. Distribution of respondents by duration of daily internet use

Duration of Daily Internet Use	Number of Respondents
< 1 hour	26
1 - 3 hours	37
3 - 5 hours	23
> 5 hours	14
Total	100

In Table 2, the majority of respondents (36%) were in the 41–50 age group, suggesting a predominantly middle-aged farmer population. Table 3, most respondents were junior high school graduates (34%), followed by senior high school graduates (26%). Table 3, internet access patterns revealed that the largest group (37%) used the internet for 1–3 hours daily, predominantly through 4G-capable smartphones (83%), while 5G device ownership remained limited to 17 respondents. Computer/laptop ownership (22%) and tablet

ownership were low, reflecting constrained digital capital.

3.3. Bonding Social Capital

Bonding social capital was measured through four indicators capturing the depth of internal community ties: in-group participation, norms of reciprocity, mutual trust, and support for fellow community members. The scores reflect the strength of relational bonds within the farming community in the digital village context. It can be seen in Table 5.

Table 5. Indicators and scores of bonding social capital among farmer respondents

Indicator of Bonding Social Capital	Total Score	Percentage (%)	Category
Participation in community organisations and farmer groups	350	70.00	High
Norms of reciprocity and <i>gotong royong</i> (mutual cooperation)	341	68.20	High
In-group mutual trust and solidarity	325	65.00	High
Emotional support and assistance among group members	315	63.00	High
Overall Bonding Social Capital	1,331	66.55	High

In Table 5, the overall bonding social capital score of 66.55% falls within the High category, reflecting well-established internal community cohesion. Participation in community organisations such as farmer groups (*kelompok tani*), RT/RW, PKK, LPM, and *gotong royong* activities was notably strong, with 70–75 respondents classified as actively engaged. These findings indicate a solid foundation of in-group trust and collective norms among *Kauditan Satu* farmers.

3.4. Bridging Social Capital

Bridging social capital was assessed through five indicators measuring the extent of farmers' connections with external actors, institutions, and cross-group digital communication platforms. These indicators capture the degree to which farmers transcend their immediate community boundaries to access new information, markets, and opportunities. It can be seen in Table 6.

Table 6. Indicators and scores of bridging social capital among farmer respondents

Indicator of Bridging Social Capital	Total Score	Percentage (%)	Category
Engagement with external institutions and government agencies	271	54.20	Moderate
Use of digital social networks (Whats-app, Facebook, Instagram, Telegram)	265	53.00	Moderate
Access to external agricultural information and extension services	259	51.80	Moderate
Participation in inter-village or inter-group activities	252	50.40	Moderate
Trust toward and cooperation with external actors	267	53.40	Moderate
Overall Bridging Social Capital	1,314	53.24	Moderate

The overall bridging social capital score of 53.24% falls within the Moderate category. Active use of social media platforms for agricultural networking was noted among 53 respondents (good category), while 30 used only WhatsApp or

Facebook passively, and 17 had no social network accounts. This suggests that digital connectivity infrastructure is available, but its utilisation for cross-group livelihood networking remains underdeveloped.

3.5. Livelihood Asset Pentagon

The five-dimensional livelihood asset pentagon was assessed to characterise the overall livelihood capital endowment of farmer

respondents. Each dimension was scored on a scale of 1–3 based on the Likert-derived averages, and the results are presented in the following Table 7.

Table 7. Summary of livelihood asset pentagon values for respondent farmers.

Livelihood Capital Dimension	Scale Value	Category
Natural Capital (land tenure, productivity, water, livestock)	2.58	Moderate
Human Capital (education, health, experience, skills)	2.31	Moderate
Social Capital (organisations, networks, mutual aid, participation)	2.60	Moderate
Physical Capital (facilities, infrastructure, tools, accessibility)	2.64	Moderate-High
Financial Capital (income, expenses, savings, debt)	2.01	Low-Moderate
Total Pentagon Asset Score	12.14	–

Physical capital (2.64) emerged as the strongest livelihood asset, reflecting the village's relatively adequate agricultural infrastructure, road accessibility, and irrigation systems, partly attributable to its digital village status. Financial capital (2.01) was the weakest dimension, driven by high household expenditures relative to income and limited access to formal credit. Human capital was constrained primarily by low formal educational

attainment, though long farming experience partially compensated for this deficit.

3.6. Principal Component Analysis (Pca)

To validate the construct structure of the three key variables—bonding social capital, bridging social capital, and livelihood strategies PCA was performed. The KMO values and Bartlett's Test of Sphericity results are presented below, followed by the component loading matrix. It can be seen in Table 8 and Table 9.

Table 8. Principal Component Analysis (PCA) results: KMO and Bartlett's Test of Sphericity

Variable	KMO Value	Bartlett's Chi-Square	df	p-value
Bonding Social Capital	0.865	677.223	6	< 0.001
Bridging Social Capital	0.904	1061.585	10	< 0.001
Livelihood Strategies	0.780	931.487	10	< 0.001

Table 9. Component matrix: factor loadings for all indicators across three constructs.

Indicator	Factor Loading
BD1 – Mutual trust within farmer group	0.967
BD2 – Norms of reciprocity (<i>gotong royong</i>)	0.983
BD3 – In-group solidarity and support	0.935
BD4 – Community organisation participation (bonding)	0.986
BR1 – Use of digital platforms for cross-group networking	0.965
BR2 – Access to external agricultural information	0.990
BR3 – Participation in inter-village activities	0.950
BR4 – Engagement with external institutions	0.988
BR5 – Trust toward external actors	0.987
L-NAT – Natural capital composite	0.956
L-HUM – Human capital composite	0.969
L-SOC – Social capital composite (livelihood)	0.967
L-FIN – Financial capital composite	0.924
L-PHY – Physical capital composite	0.975

All KMO values exceeded the 0.7 threshold, confirming adequate sampling adequacy. Bartlett's Test of Sphericity was significant ($p < 0.001$) for all three constructs, indicating sufficiently strong inter-indicator correlations. All factor loadings ranged from 0.924 to 0.990, demonstrating that each item contributed strongly to its respective latent construct. These results confirm the validity and

internal consistency of the measurement instruments.

3.7. Multiple Linear Regression Analysis

Multiple linear regression was performed with bonding and bridging social capital as independent variables and the total livelihood strategy score as the dependent variable. The results below present the model fit statistics and regression

coefficients Table 10 and Table 11.

Table 10. Multiple linear regression model fit statistics

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.858	0.735	0.730	5.317

Table 11. Multiple linear regression coefficients for bonding and bridging social capital

Predictor	B	Std. Error	Beta (β)	t-value	p-value
(Constant)	70.610	1.472	—	47.959	0.000
Bonding Social Capital (JBD)	-1.333	0.715	-0.696	-1.864	0.065
Bridging Social Capital (JBR)	-0.254	0.580	-0.163	-0.437	0.663

The regression model explained 73.5% of the variance in livelihood strategies ($R^2 = 0.735$). However, the individual effects of bonding social capital ($\beta = -0.696$; $p = 0.065$) and bridging social capital ($\beta = -0.163$; $p = 0.663$) were both non-significant at the $\alpha = 0.05$ level. The negative direction of the bonding coefficient suggests that excessively strong internal ties may reduce the

community's adaptability to new digital livelihood strategies.

3.8. Structural Equation Modelling (SEM)

Structural Equation Modelling (SEM) was applied to examine the total latent effects of bonding and bridging social capital on livelihood strategies, accounting for the full measurement model. The results are presented in Table 12.

Table 12. Structural Equation Modelling (SEM) results: total effects on livelihood strategies

Path	R ²	Total Effect
Livelihood Strategies (overall model)	0.770	—
Bonding Social Capital → Livelihood Strategies	—	-0.956
Bridging Social Capital → Livelihood Strategies	—	+0.079

The SEM model explained 77.0% of the variance in livelihood strategies ($R^2 = 0.770$), representing an improvement over the regression model. The total effect of bonding social capital was strongly negative (-0.956), indicating that over-reliance on internal social bonds significantly constrains farmers' ability to adopt and benefit from digital livelihood innovations. Bridging social capital showed a small but positive total effect (+0.079), suggesting that cross-group connections and external networking, though currently limited, can incrementally enhance livelihood strategy diversity in the digital village context.

4. DISCUSSION

4.1. Bonding Social Capital: Strengths, Paradoxes, and the Digital Transformation Context

The finding that bonding social capital in *Kauditan Satu* Village is classified as high (66.55%) reflects a well-established tradition of communal solidarity, collective norms, and in-group trust that is characteristic of long-settled agricultural communities in the Minahasa cultural region of North Sulawesi. The strong participation rates observed in community organization including farmer groups (*kelompok tani*), neighbourhood associations (*RT/RW*), and cooperative labour practices (*gotong royong*) are consistent with findings from studies on similar smallholder farming communities in Eastern Indonesia, where dense interpersonal networks function as informal safety nets and collective resource management systems. These forms of internal social capital provide significant functional benefits: they reduce transaction costs in collective agricultural activities, facilitate the dissemination of farming knowledge

within the group, and create mutual insurance mechanisms that help households manage production risks and seasonal income volatility.

However, the results of the SEM analysis introduce a critically important nuance: bonding social capital exerted a strong negative total effect (-0.956) on livelihood strategies, indicating that the strength of internal social ties may paradoxically constrain the community's capacity to diversify and adapt its livelihoods under digital transformation conditions. This counterintuitive finding is theoretically coherent with the concept of "bonding capital lock-in," wherein overly homogeneous and inward-looking social networks create echo chambers that reinforce existing practices, resist externally-originated innovations, and discourage members from pursuing opportunities that fall outside the norms of the group. In the context of *Kauditan Satu* Village's digital village programme, this dynamic may manifest as a reluctance to adopt e-commerce platforms, mobile banking, or digital

extension services, even when these tools are formally available and promoted by village and district authorities.

The negative association also reflects the structural composition of the farming community: the dominant age group (41–50 years) and predominantly lower-secondary educational attainment indicate a cohort that has been socialised into traditional livelihood norms and may face greater cognitive and technological barriers to digital engagement. The strong cultural alignment within the community while generating social solidarity may also create normative pressures that discourage early adopters of digital farming tools from deviating too far from established practices. This is consistent with findings from comparative studies in Southeast Asia which have demonstrated that strong in-group bonding can crowd out bridging connections, thereby limiting farmers' exposure to external market signals and innovation networks. The policy implication is that interventions targeting livelihood improvement in digital villages must deliberately invest in mechanisms that open bonding communities to external knowledge flows, rather than simply deepening existing community organisations.

The validation of bonding social capital through PCA yielded excellent results, with factor loadings ranging from 0.935 to 0.986 and a KMO of 0.865. This confirms that the four bonding indicators in-group trust, norms of reciprocity, community organisation participation, and mutual emotional support constitute a coherent and uni-dimensional construct. The strong internal validity of the measurement model lends confidence to the interpretation of the negative regression and SEM effects, suggesting that the negative relationship reflects a genuine structural dynamic rather than a measurement artefact. Future research could further decompose bonding capital into its normative, cognitive, and structural sub-dimensions to identify which specific aspects most strongly constrain digital livelihood adoption.

4.2. Bridging Social Capital: Digital Networks and Developmental Potential

The moderate level of bridging social capital (53.24%) in *Kauditan Satu* Village suggests that while farmers have begun to engage with external social networks and digital communication platforms, this engagement remains shallow and unevenly distributed across the community. The positive, though modest, total effect of bridging social capital on livelihood strategies (+0.079) in the SEM model is

theoretically significant: it provides empirical support for the proposition that outward-oriented social connections—even when currently limited—have the capacity to incrementally enhance livelihood diversification and resilience in digitally-enabled rural contexts. Specifically, farmers who actively utilize multi-platform digital social networks (WhatsApp, Facebook, Instagram, Telegram) for cross-group agricultural networking reported better access to external market information, agricultural extension updates, and input supply opportunities, all of which are essential components of contemporary smallholder livelihood strategies.

The pattern of digital platform use observed among respondents reveals important heterogeneity within the bridging social capital dimension. A substantial proportion of respondents (53%) were active on multiple digital platforms, functioning as digital bridging agents within and beyond the community. However, 30% relied exclusively on Facebook or WhatsApp for passive information consumption rather than active network building, while 17% had no social network accounts at all. This distribution closely mirrors findings from studies on digital divide dynamics in Indonesian rural communities, where internet access is a necessary but insufficient condition for social capital bridging: the quality and intentionality of digital social engagement whether information is actively sought, shared, or used to build cross-institutional relationships determines whether digital tools translate into livelihood gains. The relatively short daily internet access durations observed (60% of respondents using the internet for three hours or less daily) further suggest that digital platform use has not yet been fully integrated into farmers' routine livelihood strategies.

Bridging social capital's positive effect on livelihoods is most powerfully realised when farmers establish connections with institutional actors beyond their immediate community including sub-district agricultural extension offices, input cooperatives, downstream market agents, and rural financial institutions. The moderate scores on inter-village participation and engagement with external institutions indicate that these linkages exist but are inconsistently maintained. Strengthening bridging social capital in *Kauditan Satu* Village will require targeted programmes that build farmers' capacity to leverage digital tools for strategic networking rather than merely recreational use. Agricultural extension services delivered

through digital platforms, market information systems accessible via smartphone applications, and facilitated inter-group knowledge exchange networks represent practical pathways to transform latent bridging connections into active livelihood assets.

The PCA results for bridging social capital were particularly strong, with a KMO of 0.904 and factor loadings between 0.950 and 0.990. This high level of construct validity indicates that the five bridging indicators—digital platform use, external institution engagement, access to external information, inter-village participation, and trust in external actors capture a coherent and robust latent construct. The high loading of the external information access indicator (0.990) is especially noteworthy, as it positions information brokerage at the core of bridging capital in the digital village context. Future studies should examine whether bridging capital effects are more pronounced for specific livelihood outcome dimensions—such as financial capital accumulation or agricultural market integration—which may more directly benefit from cross-group network activation.

4.3. Livelihood Asset Configuration and Vulnerability Analysis

The livelihood asset pentagon analysis reveals a community that is reasonably well-endowed in physical and social capital, moderately positioned in natural capital, but significantly constrained in both human and financial capital. This asset profile reflects the structural conditions typical of semi-peri-urban agricultural communities in North Sulawesi, where government-supported rural infrastructure development including road improvement, irrigation construction, and the digital village programme itself—has enhanced physical capital endowments, while educational investment and financial inclusion have lagged behind. Physical capital's leading score (2.64) is consistent with the village's designation as a digital village, which has catalysed improvements in connectivity infrastructure, access roads, and irrigation facilities. The moderate score for social capital as a livelihood asset (2.60) is aligned with the high bonding capital findings and reflects the community's active participation in formal and informal social institutions.

The lowest score for financial capital (2.01) represents the most critical vulnerability in the livelihood portfolio. The analysis revealed that while 60% of respondents earned above Rp 4,000,000 per month from farming and

supplementary income sources, the majority (57%) reported monthly expenditures exceeding IDR 3,000,000, leaving minimal surplus for savings or investment. High debt burdens with 37 respondents carrying multiple loans above IDR 5,000,000 further constrain financial resilience and limit investment capacity in digital agricultural tools or value-added processing. This debt structure suggests that financial capital not only limits livelihood diversification in the short term but also creates vulnerability to income shocks, particularly in the context of agricultural price volatility and the climate-related risks that affect tropical smallholder farming systems. Strengthening financial capital will require multi-pronged interventions encompassing microfinance access improvements, financial literacy training, and the development of community-based savings and credit institutions (*koperasi*) aligned with the digital village framework.

Human capital, with the second-lowest score (2.31), reflects the educational composition of the respondent population. The predominance of lower-secondary graduates (34%) and primary school graduates (21%) creates a structural constraint on farmers' ability to engage with complex digital platforms, interpret market data, or participate in formal value chain networks. However, it is important not to conflate formal educational attainment with practical agricultural competence: the finding that 45% of respondents possessed more than 25 years of farming experience, and that 50% were classified as having good skills and expertise, indicates a substantial stock of experiential human capital that digital village programmes must leverage rather than overlook. Training programmes designed to translate existing practical expertise into digitally-enabled livelihood strategies rather than imposing external technological frameworks are likely to be more effective and culturally resonant.

Natural capital (2.58) reflects generally adequate agricultural resources, supported by the village's fertile volcanic soils and well-developed water infrastructure. The construction of government-supported water reservoirs (*embung*) has significantly improved water availability for 80 respondents, while strong land tenure security for 71 respondents provides a stable foundation for long-term agricultural investment. However, limited livestock diversity—with 64% of respondents owning only one to three types of farm animals—indicates underutilised opportunities for diversification into higher-value animal husbandry

products. The integration of digital tools for livestock management and market linkage could serve as an entry point for bridging capital development in the natural capital dimension.

4.4. Digital Technology as Social Capital Mediator: Opportunities and Constraints

The digital village designation of *Kauditan Satu* Village provides a distinctive lens through which to examine the intersection of ICT infrastructure and social capital dynamics. The present study finds that digital technology operates as both an enabler and a potential disruption of social capital in the agricultural community. On the enabling side, digital platforms particularly WhatsApp and Facebook groups used for farmer coordination have strengthened certain dimensions of bonding capital by enabling continuous communication among community members, reducing coordination costs for collective activities, and facilitating rapid information sharing about input prices, weather conditions, and crop pest outbreaks. These applications of digital technology extend and amplify the traditional functions of bonding capital, creating what might be termed a "digital bonding layer" atop existing community social networks.

At the same time, the potential of digital technology to build bridging capital by connecting farmers with external actors, markets, and knowledge systems has been only partially realised in *Kauditan Satu* Village. The relative passivity of much digital platform use (information consumption rather than active network building) mirrors findings from comparable studies across rural Southeast Asia, where digital tool adoption for agricultural livelihood purposes often remains shallow unless supported by structured digital extension services and community digital literacy programmes. The 17% of respondents with no social media presence represents a significant segment of the community that is entirely excluded from digital bridging benefits, a finding that warrants targeted attention from both village administration and regional agricultural extension services.

The relationship between digital access and social capital in *Kauditan Satu* Village also reflects broader digital equity concerns. The predominance of 4G device ownership (83%) over 5G (17%), combined with relatively short daily internet access durations and limited computer or laptop ownership (22%), suggests that the community's digital capital is concentrated primarily in smartphone-based mobile internet access. While

smartphones are versatile tools for basic social networking and information access, their limited screen size and processing power constrain higher-value agricultural applications such as precision farming platforms, satellite-based crop monitoring, or complex market analysis dashboards. Expanding the digital capital base of the village—through shared computing facilities, community ICT hubs, and targeted device access programmes could substantially enhance the bridging capital potential of digital technology.

The complex interplay between bonding capital, bridging capital, and digital technology adoption in *Kauditan Satu* Village suggests a need for a sequenced approach to livelihood intervention. In the short term, leveraging existing bonding capital structures particularly the active farmer groups as delivery channels for digital literacy training and agricultural market information services can help embed digital tools within trusted social relationships. Over the medium term, deliberate efforts to build bridging capital through facilitated connections with external extension services, agribusiness enterprises, and digital market platforms are essential to unlock the positive livelihood effects that bridging capital can generate. In the long term, a comprehensive digital social capital framework that integrates both bonding and bridging dimensions supported by appropriate ICT infrastructure, financial inclusion services, and human capital development is required to make *Kauditan Satu* Village's digital village designation translate into lasting livelihood improvement.

4.5. Policy Implications for Digital Village Livelihood Development

The findings of this study carry important implications for the design and implementation of digital village policies in Indonesia and analogous contexts. First, the strong negative effect of bonding social capital on livelihood strategies under digital transformation conditions challenges the conventional wisdom that community cohesion is uniformly beneficial for rural development. Policymakers and programme designers must recognise that excessively inward-oriented communities may require deliberate interventions to "open" their social networks to external actors and innovations. This is not a call to undermine community solidarity which serves critical welfare and resilience functions but rather to complement it with structured bridging capital development. Farmer exchange visits, inter-village digital innovation competitions, and cross-district

agricultural value chain partnerships are practical instruments that can stimulate bridging connections without disrupting existing community cohesion.

Second, the moderate level of bridging social capital and its positive effect on livelihoods underscore the critical importance of digital extension services as a mechanism for building cross-group agricultural networks. The current reliance on informal social media use for agricultural information is insufficient to generate the quality of bridging capital needed for significant livelihood diversification. The establishment of structured digital extension platforms accessible via the Village Information System (SID) and integrated with Whats-app-based farmer consultation services—would formalise and enhance the bridging capital function of digital technology in *Kauditan Satu* Village. Evidence from comparable digital village programmes in Java and Sumatra suggests that government-facilitated digital extension delivers greater livelihood impact when embedded within existing community social structures rather than imposed as stand-alone technological interventions.

Third, the financial capital deficit identified in the livelihood pentagon analysis demands coordinated action across multiple policy domains. The expansion of government-backed microfinance programmes targeting smallholder farmers, combined with village-level financial literacy education and the integration of digital payment systems into agricultural value chains, would address the structural financial vulnerability of *Kauditan Satu* farmers. The Village Fund (*Dana Desa*) allocation mechanism should prioritise financial capital strengthening interventions alongside ICT infrastructure investment, recognising that digital tools can only generate sustainable livelihood benefits when users possess adequate financial resources to invest in and maintain access to them.

Fourth, the human capital constraint particularly the low formal educational attainment of the farmer population necessitates adult education and vocational training programmes tailored to the specific skill requirements of digital agriculture. Rather than generic ICT literacy training, programmes should focus on application-specific skills directly relevant to farmers' livelihood activities: digital market navigation, agricultural e-commerce platforms, mobile banking for input procurement, and the use of weather and crop monitoring applications. These practical, outcome-oriented training approaches are more likely to be

adopted and sustained by farmers with limited formal education than abstract computer literacy curricula. Collaboration between the village government, Sam Ratulangi University's agricultural faculty, and the sub-district agricultural extension service would be an effective institutional mechanism for delivering such programmes in *Kauditan Satu* Village.

Finally, the findings call for a more nuanced monitoring and evaluation framework for Indonesia's digital village programme that moves beyond infrastructure deployment metrics to assess the social capital and livelihood outcomes of digital transformation. Currently, digital village evaluation tends to focus on connectivity penetration, digital service adoption rates, and government service digitalisation indices. The evidence presented in this study suggests that these metrics are necessary but insufficient; they must be supplemented by social capital assessments that track both the bonding and bridging dimensions of community social networks, as well as livelihood pentagon monitoring that identifies which capital dimensions are strengthening or weakening over time. Such evidence-based monitoring would enable adaptive management of the digital village programme and ensure that investment in digital infrastructure translates into genuine and equitable livelihood improvement for rural farming communities across Indonesia.

5. CONCLUSION

This study examined the levels and livelihood effects of bonding and bridging social capital among 100 farmer respondents in *Kauditan Satu* Village, the first integrated digital village in North Minahasa Regency, North Sulawesi, Indonesia. Bonding social capital was found to be high (66.55%), reflecting robust internal community cohesion and active participation in farmer organisations and cooperative labour practices. Bridging social capital was at a moderate level (53.24%), indicating that cross-group digital networking and engagement with external institutions, while present, remain underdeveloped relative to their potential. The livelihood asset pentagon showed physical capital as the strongest dimension (2.64) and financial capital as the most critical constraint (2.01), with a total pentagon score of 12.14.

The results of PCA, multiple linear regression, and SEM analyses revealed a paradox central to the digital livelihood transformation of this community: bonding social capital, while high

in absolute terms, exerted a strong negative total effect on livelihood strategies ($\beta = -0.956$ in SEM), suggesting that excessive inward social orientation may constrain openness to digital innovation. Bridging social capital, despite its moderate level, demonstrated a positive though small effect (+0.079), affirming its potential as a catalyst for livelihood diversification and digital economic participation. Both regression and SEM models explained over 70% of the variance in livelihood strategies, confirming the analytical relevance of social capital for understanding livelihood dynamics in digital village contexts.

These findings point to three priorities for policy and practice: (1) deliberate investment in bridging capital development through structured digital extension services and inter-community networking programmes; (2) targeted interventions to address the financial capital deficit through accessible rural microfinance and digital payment systems; and (3) practical, application-oriented digital literacy programmes that build on farmers' existing agricultural expertise rather than imposing generic ICT training. Future research should extend this analysis to comparative digital village contexts across Indonesia, employing longitudinal designs to track the evolution of social capital and livelihood

outcomes as digital transformation matures. A mixed-methods approach that complements quantitative SEM with qualitative case studies would further enrich understanding of the mechanisms through which bonding and bridging social capital interact with digital technologies to shape farmer livelihoods.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Charles R. Ngangi (CRN): Conceptualisation, data curation, formal analysis, supervision, writing - original draft, writing - review and editing. Rine Kaunang (RK): Methodology, field research, data collection, writing - review and editing. Stephano C.W. Ngangi (SCWN): Formal analysis, visualisation, writing - review and editing."

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