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What shapes rural resilience and vulnerability? Evidence from a global meta-analysis

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Abstract

Rural vulnerability and resilience are intrinsically linked yet denote non-equivalent dimensions of how rural communities experience and respond to risk. Yet the existing literature tends to synthesize these concepts separately or treat them as inverse proxies, leaving it unclear whether particular determinants signify shared adaptive capacities or merely reflect exposure, recovery, or structural dependence. This study employs paired yet independent meta-analytic syntheses of quantitative rural evidence, reconciling reported associations while carefully preserving the conceptual separation between the two outcomes. Three findings emerge: (1) A convergent capacity core appears across both syntheses: education, health, socioeconomic resources, physical and natural capital, and adaptive livelihood strategies consistently correspond with lower vulnerability and higher resilience, whereas heavy agricultural dependence displays a divergent trend. (2) The convergence between the two syntheses is, however, incomplete: exposure, financing, human-capital, household composition, and accessibility factors reveal outcome-specific trajectories, thereby reinforcing the notion that vulnerability and resilience capture discrete stages of the risk process rather than opposing ends of a linear continuum. (3) The associations vary substantially across studies, precluding the identification of stable global effect magnitudes. This variability likely stems from differences in contextual, methodological, or specification choices. The synthesis therefore advocates using global evidence as a diagnostic scaffold for locally grounded assessment, rather than as a basis for ranking universal interventions.

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Keywords: rural resilience; rural vulnerability; rural development; meta-analysis; livelihood diversification; agricultural dependence

1. Introduction

Rural communities face acute shocks such as floods and droughts alongside slower pressures including population loss, insecure livelihoods, weak service provision, infrastructure deficits, and ecological decline. The consequences of these pressures extend well beyond their sites of occurrence, insofar as rural areas underpin food production, ecosystem management, cultural landscapes, and regional economies. Disaster resilience research has long demonstrated that outcomes depend not only on the severity of a shock but also on pre-existing social, economic, ecological, and institutional conditions (Cutter et al., 2008; Norris et al., 2008; Berkes & Ross, 2013). These conditions assume particular significance in rural settings, where settlement patterns are dispersed, access to services often entails considerable cost, livelihoods may be directly contingent upon climate-sensitive resources, and protracted decline can erode the capacities required for adjustment and recovery (McManus et al., 2012; Kapucu et al., 2013; Boon, 2014). Recent China-based studies likewise demonstrate that rural disaster outcomes reflect both community-level response capacities and spatial inequalities in infrastructure, governance, and access to support (Li et al., 2024; Li et al., 2025).

The empirical literature has expanded rapidly across hazards and development contexts, including climate change, floods, droughts, food insecurity, poverty, resettlement, and ecological change. Yet the evidence remains difficult to compare. Education, health, household resources, social cohesion, infrastructure, finance, ecological assets, livelihood strategies, and agricultural dependence recur across studies, but they are measured at disparate scales and embedded within divergent model specifications. Outcome conceptualizations likewise vary. Some studies treat vulnerability as an approximate inverse of resilience, whereas others define resilience more narrowly as the capacity to absorb, adapt, learn, or transform. Methodological approaches range from composite indices and household regressions to participatory assessment, spatial analysis, machine learning, and scenario simulation. Recent reviews accordingly characterize the field as expanding yet methodologically fragmented (Chen et al., 2025). A rural-focused systematic review similarly emphasizes resistance, adaptation, and transformation as distinct components of resilience, while highlighting the role of social capital and rural transformation in strengthening adaptive capacity (Li, 2023). Related work has measured farmers' sustainable livelihood resilience through buffer capacity, self-organization

capacity, and learning capacity, illustrating the multidimensional character of livelihood resilience assessment (Sun et al., 2023).

This conceptual distinction is not merely semantic. Vulnerability is most directly concerned with exposure and susceptibility to harm prior to and during disruption. Resilience additionally concerns what follows: persistence, coping, adjustment, learning, and recovery. A determinant may therefore be relevant to both outcomes without exhibiting the same strength, timing, or empirical signature. Treating resilience as the simple inverse of vulnerability obscures whether rural disadvantage is driven primarily by exposure, by limited capacity to respond, or by structural dependence on livelihoods and services that are difficult to substitute.

Existing frameworks provide strong foundations for analysing these processes, including the Disaster Resilience of Place model, baseline resilience indicators, adaptive-capacity approaches, and socio-ecological perspectives (Cutter et al., 2008; Cutter et al., 2010; Norris et al., 2008; Summers et al., 2017; Berkes & Ross, 2013). Work on operational resilience also emphasizes linkages among disaster-risk reduction, sustainable development, and community engagement (Djalante & Thomalla, 2010). The unresolved empirical question is more narrowly defined: whether determinant domains exhibit concordant average associations across separately studied vulnerability and resilience outcomes, and where the observed patterns diverge. Only two of the 60 included studies report both outcomes, so the literature offers little direct within-study evidence on this question. Measures bearing the same label also differ across index studies, household regressions, community assessments, and spatial models. A paired synthesis can therefore be informative, but it must distinguish recurrent cross-study patterns from formal evidence that a determinant exerts differential effects on vulnerability and resilience.

We address this problem with paired yet separate meta-analytic syntheses of vulnerability and resilience. The analysis addresses three questions: which determinant domains exhibit recurrent average associations with each outcome; where do the two syntheses show concordance or descriptive divergence; and how much confidence should be placed in average associations when studies differ sharply in context, measurement, and adjustment. We employ the term “shared capacity core” as shorthand for domains exhibiting concordant average directions across the two separate syntheses, not as evidence of a common causal effect. Likewise, “resilience-vulnerability asymmetry” refers here to descriptive cross-synthesis divergence, not to a formal statistical contrast between outcomes. The contribution is therefore comparative and diagnostic: it identifies recurring capacity domains and structural constraints

while making explicit the limits imposed by heterogeneous estimands, uneven evidence coverage, and pronounced between-study heterogeneity.

2. Research methodology

2.1 Search strategy, eligibility criteria, and study coding

The review process was structured in accordance with PRISMA 2020 (Page et al., 2021). The archived review records document searches of Web of Science (searched on 5 April 2025), Wiley Online Library (searched on 3 April 2025), PubMed (searched on 6 April 2025), and ScienceDirect(searched on 18 April 2025) over the 1990–2024 publication window using the core terms “rural resilience”, “rural vulnerability”, “community resilience”, and “community vulnerability”. Four reviewers independently searched their assigned databases and initially screened the retrieved records by title and abstract; the database-specific sets were then merged, duplicates were removed (EndNote), and the combined records were assessed in full text. Figure 1 reports the screening sequence preserved in the review archive: 80,477 records entered title-and-abstract screening after the database-specific exclusions shown in the figure, 5,750 records remained after merging and re-screening, 4,042 full texts were assessed, and 60 studies entered the quantitative synthesis. The substantial reduction reflects the narrow substantive and statistical eligibility rules rather than evidence that the initial search set was representative of the rural-resilience literature as a whole.

Studies were eligible when they identified a rural study area and sample size, measured resilience or vulnerability quantitatively, examined at least one potential determinant, and reported a statistic suitable for extraction or conversion. For the descriptive synthesis, we coded study location, national income context, predisposing stressor, outcome, sample size, and assessment method. Determinants were grouped only when the operational definitions in the source extraction were substantively comparable; Table 1 makes these groupings explicit so that broad labels such as human capital, natural capital, and risk financing are not interpreted more narrowly than the underlying measures warrant. Table A.1 lists the 60 study records and the characteristics retained for analysis.

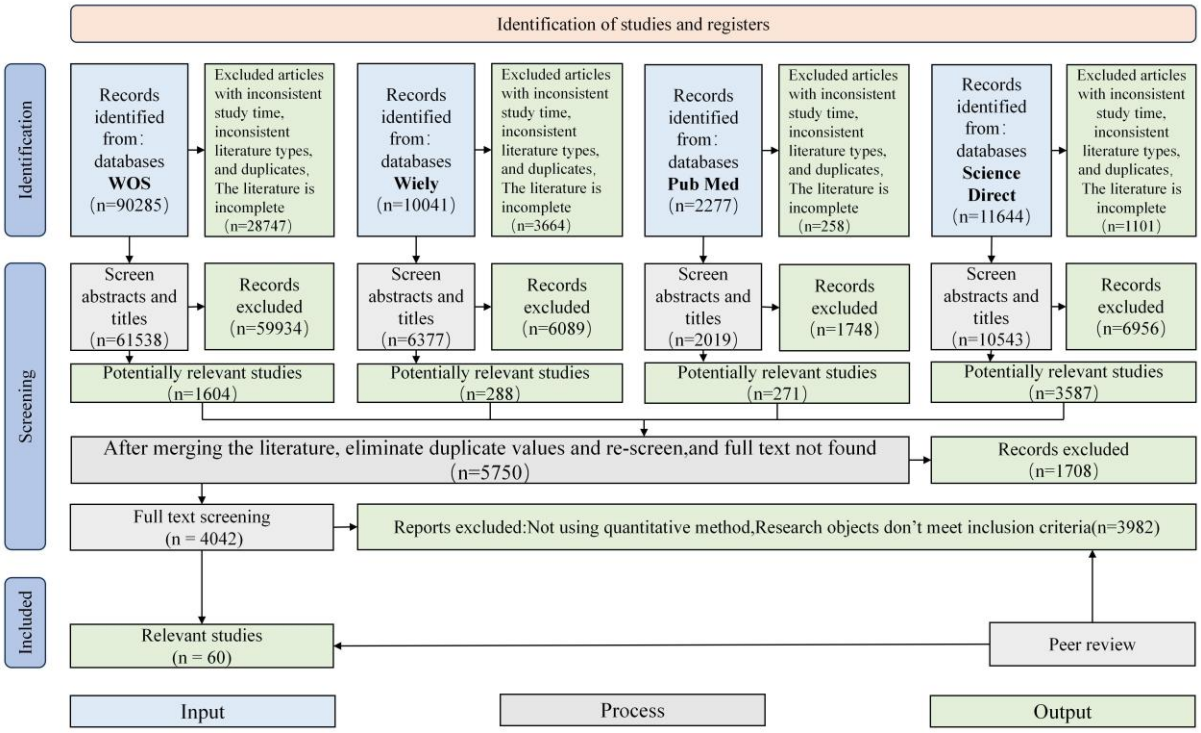


Figure 1. Study identification and screening flow recorded in the review archive.

2.2 Effect-size harmonization and unit of analysis

The included studies reported heterogeneous effect statistics. Pearson correlations were retained where available, while regression-derived and other convertible statistics were transformed to correlation-type associations using established procedures (Peterson & Brown, 2005; van Aert, 2023). Effect directions were harmonized so that the estimates could be synthesized on a common correlation scale. Because these measures include both zero-order and adjusted associations, we denote the pooled statistic as r* and interpret it as a harmonized association rather than a common causal effect.

Associations were analyzed on Fisher's z scale and transformed back to r* for presentation. Determinants were grouped according to the operational definitions in Table 1, and the intended unit of analysis was the study. The archived data do not fully document the selection of multiple estimates within some studies, so within-study dependence cannot be reconstructed with certainty. Vulnerability and resilience were therefore synthesized separately, and cross-outcome differences are treated as descriptive rather than formal statistical contrasts.

Table 1. Operational definitions of determinants included in the rural vulnerability and resilience syntheses. Study IDs refer to Table A.1.

Dependent variable	Influencing factor	Variable description	Example study ID (Table A.1)
Rural vulnerability	Education	Educational attainment or status of the household head/respondent	18

Dependent variable	Influencing factor	Variable description	Example study ID (Table A.1)
	Gender	Sex/gender of the household head or household measure, as defined in the source study	19
	Health	Respondent health status, as defined in the source study	24
	Age	Age of the household head or respondent, as defined in the source study	48
	Risk financing	Access to formal credit, insurance, or related risk-financing mechanisms	53
	Family size	Number of household members	53
	Social capital / social cohesion	Community identity, participation, mutual support, and social cohesion	47
	Economic conditions	Household income, expenditure, or related indicators of economic resources	53
	Agricultural dependence	Extent of household reliance on agriculture, measured through primary income source, agricultural-income share, or farming labor	59
	Physical capital	Tangible household or productive assets and related physical resources	52
	Natural capital	Access to or endowment of natural resources and ecosystem assets, including water, forest, and agricultural land	4
	Human capital	Labor availability or related human-capital measures used in the source study	19
	Natural disaster	Exposure to natural hazards such as droughts, floods, or cold waves	11
	Adaptive livelihood strategies	Strategies adopted to anticipate, cope with, or respond to livelihood and disaster risks	8
Rural resilience	Education	Educational attainment or status of the household head/respondent	7
	Gender	Sex/gender of the household head or household measure, as defined in the source study	15
	Health	Respondent health status, as defined in the source study	16
	Age	Age of the household head or respondent, as defined in the source study	2
	Risk financing	Access to formal credit, insurance, or related risk-financing mechanisms	21
	Experience	Previous disaster experience and learning derived from past exposure	6
	Family size	Number of household members	17
	Social cohesion	Community identity, participation, mutual support, and social cohesion	28
	Economic conditions	Household income, expenditure, or related indicators of economic resources	23
	Agricultural dependence	Extent of household reliance on agriculture, measured through primary income source, agricultural-income share, or farming labor	7
	Distance	Distance or accessibility to markets, water sources, or other key resources	13
	Physical capital	Tangible household or productive assets and related physical resources	33
	Natural capital	Access to or endowment of natural resources and ecosystem assets, including water, forest, and agricultural land	32
	Human capital	Labor availability or related human-capital measures used in the source study	28

Dependent variable	Influencing factor	Variable description	Example study ID (Table A.1)
	Natural disaster	Exposure to natural hazards such as droughts, floods, or cold waves	21
	Adaptive livelihood strategies	Strategies adopted to anticipate, cope with, or respond to livelihood and disaster risks	45

2.3 Meta-analytic synthesis, heterogeneity, and small-study diagnostics

Vulnerability and resilience were synthesized separately using the random-effects results retained in the source analysis. Cochran's Q and I^2 were used to describe between-study heterogeneity. Given the diversity of settings, outcome constructions, and model specifications, the random-effects mean is interpreted only as an average association across the available studies, not as a common effect for rural populations. Prediction intervals would provide a more direct indication of the range expected in a new setting, but they cannot be reconstructed reliably from the aggregate tables because the effect-level sampling variances and between-study variance estimates are not retained. The same constraint precludes a defensible retrospective meta-regression of contextual moderators. Accordingly, high I^2 is treated as evidence of inconsistency; its source cannot be attributed to context rather than measurement or model specification from the retained data alone.

Funnel plots and Egger regressions were used as diagnostics for small-study effects, not as direct tests of publication bias. We emphasize syntheses with approximately ten or more studies because asymmetry tests have low power at smaller k and can also respond to heterogeneity or other features of the evidence base (Sterne et al., 2011). All reported p values are nominal; no multiplicity adjustment was applied across the many determinant-level syntheses. We therefore emphasize direction, confidence intervals, number of contributing studies, heterogeneity, and cross-outcome concordance rather than binary significance thresholds. The original extraction did not include a formal study-level risk-of-bias assessment, and we did not construct a numerical score retrospectively from incomplete information. ROBINS-E is relevant to many non-randomized exposure designs, although it does not cover every design included here (Higgins et al., 2024).

3. Research results

3.1 Research landscape and study characteristics

The 60 included studies span a wide geographic area, but the evidence is unevenly distributed. Asia and Africa account for a substantial share of the literature, with a pronounced concentration in lower-middle-income and low-income settings where climate variability,

poverty, and constrained service access constitute prevailing concerns. Figure 2 further illustrates a pronounced temporal concentration. Although the search window commenced in 1990, the retained study inventory begins in 2015, and publication activity accelerates sharply from the late 2010s. The synthesis therefore possesses global geographic reach, but is not statistically representative of rural populations worldwide.

Of the 60 studies, 41 focus on resilience as the primary outcome, 17 target vulnerability, and two report both. The majority were published from 2022 onwards, comprising 20 in 2023 and 15 in 2024. Sample sizes range from 45 to 11,471, spanning small, site-specific household surveys to considerably larger regional or national datasets. Since only two studies contribute to both outcomes, the paired synthesis compares two largely distinct evidence bases. This characteristic is pivotal for interpretation: concordance is informative about recurring patterns, whereas observed divergences between outcomes may equally arise from differences in study composition.

The studies also differ with respect to the stressors used to frame resilience or vulnerability assessment. Some examine discrete shocks; others concentrate on protracted, cumulative stresses. Climate change, drought, floods, food insecurity, poverty, and related environmental pressures represent the most recurrent themes. This breadth facilitates comparison across diverse forms of rural risk, although it also implies that a given determinant may exert effects through varying mechanisms across settings. Table A.1 provides the full study-level inventory.

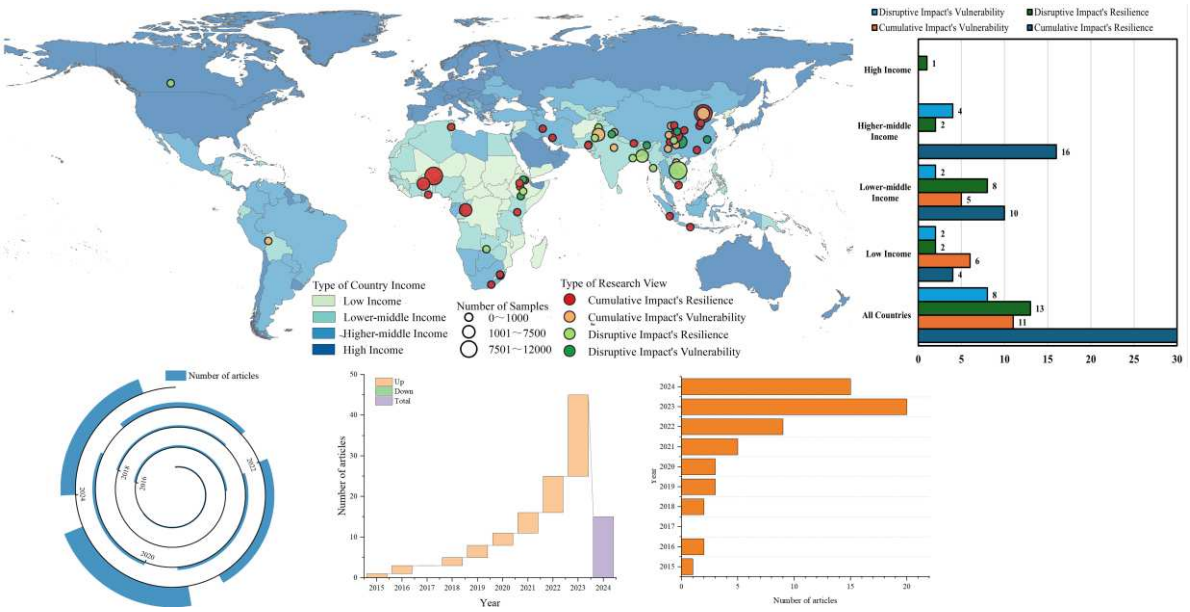


Figure 2. Global distribution and research profile of studies on rural resilience and vulnerability.

3.2 Determinants of rural vulnerability and resilience

As shown in Table 2, in the vulnerability synthesis, several capacity-related domains had negative pooled associations. Health had the largest absolute pooled estimate (r* = -0.370, 95% CI -0.588 to -0.102, p = 0.008), but it was based on only four studies and was extremely heterogeneous (I^2 = 99.2%). Adaptive livelihood strategies (r* = -0.241, p = 0.002), natural capital (r* = -0.208, p = 0.001), economic conditions (r* = -0.168, p = 0.037), social capital (r* = -0.166, p = 0.012), education (r* = -0.162, p < 0.001), and physical capital (r* = -0.129, p = 0.045) also had negative pooled means. These magnitudes should not be ranked causally because r* combines zero-order and partially adjusted associations, study counts differ by determinant, and the p values are unadjusted for multiplicity.

Agricultural dependence had a positive pooled association with vulnerability (r* = 0.301, 95% CI 0.082 to 0.493, p = 0.008), as did natural-disaster exposure (r* = 0.226, p = 0.001). The female-coded gender indicator had a small positive pooled mean (r* = 0.083, p = 0.044), whereas the corresponding male-coded estimate was imprecise. Age, risk financing, family size, and the broad human-capital measure had confidence intervals that included zero. Heterogeneity was substantial: I^2 exceeded 90% for every vulnerability estimate except the female-coded gender indicator and family size. The evidence therefore supports recurring average directions more strongly than stable effect magnitudes.

The key result is therefore directional rather than ordinal. Several capacity-related domains have negative pooled means and agricultural dependence and hazard exposure have positive pooled means, but the very high I^2 values rule out treating any of these as a stable global coefficient. Heterogeneity also cannot be attributed to context alone because outcome construction, covariate adjustment, and study design vary across the evidence base.

Table 2. Pooled harmonized associations (r*) and heterogeneity for rural vulnerability.

		Pooled r* and 95% CI			Test of pooled mean		Heterogeneity			
Influencing factor		**k**	**r***	**95% CI lower**	**95% CI upper**	**z**	**p**	**Q**	**df**	**p**	**I^2**
Education		10	-0.162	-0.244	-0.079	-3.790	<.001	203.3	9	<.001	95.6
Gender	Female	4	0.083	0.002	0.162	2.013	0.044	11.4	3	0.010	73.7
	Male	3	-0.100	-0.322	0.134	-0.835	0.404	59.0	2	<.001	96.6
Health		4	-0.370	-0.588	-0.102	-2.658	0.008	356.9	3	<.001	99.2
Age		5	0.103	-0.008	0.212	1.816	0.069	111.7	4	<.001	96.4
Risk financing		6	-0.100	-0.369	0.185	-0.683	0.495	337.0	5	<.001	98.5

		Pooled r* and 95% CI			Test of pooled mean		Heterogeneity			
Family size	4	-0.049	-0.135	0.037	-1.114	0.265	17.7	3	0.001	83.0
Social capital	9	-0.166	-0.290	-0.036	-2.505	0.012	152.7	8	<.001	94.8
Economic conditions	11	-0.168	-0.319	-0.010	-2.082	0.037	386.5	10	<.001	97.4
Agricultural dependence	7	0.301	0.082	0.493	2.663	0.008	330.9	6	<.001	98.2
Physical capital	11	-0.129	-0.252	-0.003	-2.003	0.045	214.8	10	<.001	95.3
Natural capital	9	-0.208	-0.321	-0.088	-3.380	0.001	127.6	8	<.001	93.7
Human capital	4	-0.040	-0.264	0.189	-0.336	0.737	50.3	3	<.001	94.0
Natural-disaster exposure	8	0.226	0.100	0.345	3.469	0.001	112.0	7	<.001	93.8
Adaptive livelihood strategies	7	-0.241	-0.383	-0.088	-3.065	0.002	103.5	6	<.001	94.2

Note. r denotes the harmonized correlation-type association. Reported p values are two-sided and nominal; no multiplicity adjustment was applied. I^2 quantifies between-study inconsistency, not its source. Because contributing estimates include zero-order and adjusted associations, pooled magnitudes should not be interpreted as causal rankings.*

Only education, economic conditions, and physical capital had approximately ten or more contributing vulnerability studies, the range in which Egger regressions become more interpretable. Their two-sided p values were 0.256, 0.626, and 0.833, respectively, providing no detected asymmetry signal. Family size produced a nominal p value of 0.034, but that synthesis contained only four studies and is too small for a reliable inference about selective reporting. The remaining tests were similarly underpowered. Figure 3 and Table 3 should therefore be read as small-study diagnostics rather than evidence that publication bias is either present or absent.

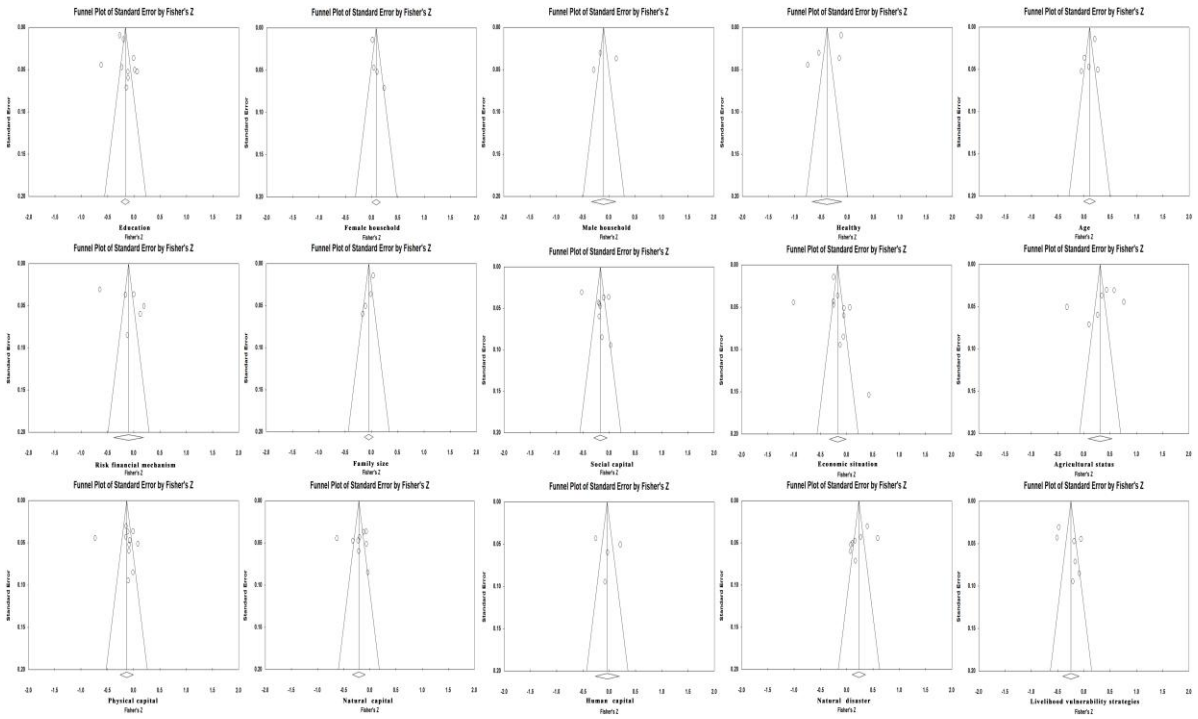


Figure 3. Funnel plots for small-study-effect diagnostics in rural vulnerability syntheses.

Table 3. Egger regression diagnostics for rural vulnerability syntheses.

Influencing factor		Intercept	SE	95% CI lower	95% CI upper	t	df	p (1-tailed)	p (2-tailed)
Education		2.753	2.250	-2.436	7.942	1.224	8	0.128	0.256
Gender	Female	2.509	0.981	-1.713	6.730	2.557	2	0.062	0.125
	Male	-4.030	21.576	-278.174	270.114	0.187	1	0.441	0.882
Health		-13.116	6.575	-41.406	15.174	1.995	2	0.092	0.184
Age		-3.920	2.655	-12.368	4.529	1.476	3	0.118	0.236
Risk financing		14.286	10.143	-13.874	42.447	1.409	4	0.116	0.232
Family size		-3.757	0.715	-6.832	-0.681	5.256	2	0.017	0.034
Social capital		5.511	4.598	-5.360	16.383	1.199	7	0.135	0.270
Economic conditions		1.694	3.357	-5.900	9.288	0.505	9	0.313	0.626
Agricultural dependence		-12.081	9.404	-36.254	12.092	1.285	5	0.128	0.255
Physical capital		1.094	5.046	-10.321	12.509	0.217	9	0.417	0.833
Natural capital		-0.541	6.679	-16.335	15.253	0.081	7	0.469	0.938
Human capital		2.852	9.626	-38.565	44.269	0.296	2	0.397	0.795
Natural-disaster exposure		-9.323	4.953	-21.441	2.796	1.882	6	0.054	0.109
Adaptive livelihood strategies		6.244	4.023	-4.097	16.585	1.552	5	0.091	0.181

Note. Egger regressions are treated only as small-study-effect diagnostics. Interpretation relies on two-sided p values and is especially limited when k is below about 10 or heterogeneity is high.

As shown in Table 4, the resilience synthesis showed positive pooled means for a broader set of capacity-related domains. Health again had the largest absolute pooled estimate ($r^* = 0.508$, 95% CI 0.192 to 0.728, $p = 0.003$), but the estimate came from seven studies and was extremely heterogeneous ($I^2 = 99.7\%$). Positive pooled means were also observed for adaptive livelihood strategies ($r^* = 0.394$, $p < 0.001$), human capital ($r^* = 0.322$, $p = 0.003$), economic conditions ($r^* = 0.306$, $p < 0.001$), natural capital ($r^* = 0.219$, $p = 0.030$), social capital ($r^* = 0.178$, $p = 0.038$), family size ($r^* = 0.174$, $p = 0.023$), physical capital ($r^* = 0.162$, $p = 0.044$), education ($r^* = 0.155$, $p = 0.004$), and risk financing ($r^* = 0.100$, $p = 0.008$). These are pooled associations, not a ranking of causal importance, and the nominal p values should be read alongside study counts and heterogeneity.

Agricultural dependence had a negative pooled association with resilience ($r^* = -0.163$, $p < 0.001$), and greater distance from markets or water sources was also negative ($r^* = -0.104$, $p = 0.006$). Gender, age, previous disaster experience, and natural-disaster exposure had confidence intervals that included zero; the pooled exposure estimate was negative ($r^* = -0.126$, $p = 0.068$). Heterogeneity remained high, with I^2 above 80% for every resilience determinant and above 95% for many. As in the vulnerability synthesis, the direction of recurrent average associations is more defensible than their precise magnitude.

Reading the two syntheses together reveals a shared empirical pattern, but not a formal test of outcome differences. Eight determinant domains have confidence intervals excluding zero in both syntheses and show concordant directions: education, health, social capital, economic conditions, physical capital, natural capital, adaptive livelihood strategies, and agricultural dependence. The first seven have negative pooled means for vulnerability and positive pooled means for resilience, whereas agricultural dependence shows the reverse. Other patterns are less concordant: risk financing, family size, and broad human capital have intervals excluding zero only in the resilience synthesis; natural-disaster exposure does so only in the vulnerability synthesis; and distance/accessibility is available only for resilience. Because the underlying study sets differ and only two studies report both outcomes, a difference in nominal significance must not be interpreted as a statistically significant difference between vulnerability and resilience.

Table 4. Pooled harmonized associations (r*) and heterogeneity for rural resilience.

		Pooled r* and 95% CI			Test of pooled mean		Heterogeneity			
Influencing factor	**k**	**r***	**95% CI lower**	**95% CI upper**	**z**	**p**	**Q**	**df**	**p**	**I^2**

			Pooled r* and 95% CI			Test of pooled mean		Heterogeneity			
Education		21	0.155	0.050	0.256	2.891	0.004	901.2	20	<.001	97.8
Gender	Female	4	0.030	-0.134	0.192	0.356	0.722	21.8	3	<.001	86.2
	Male	10	0.107	-0.017	0.229	1.691	0.091	170.9	9	<.001	94.7
Health		7	0.508	0.192	0.728	3.003	0.003	1725.9	6	<.001	99.7
Age		13	-0.034	-0.091	0.024	-1.141	0.254	61.1	12	<.001	80.4
Risk financing		12	0.100	0.026	0.173	2.633	0.008	88.9	11	<.001	87.6
Experience		8	0.291	-0.154	0.637	1.290	0.197	1866.9	7	<.001	99.6
Family size		17	0.174	0.024	0.316	2.270	0.023	1118.1	16	<.001	98.6
Social capital		22	0.178	0.010	0.337	2.080	0.038	1932.3	21	<.001	98.9
Economic conditions		22	0.306	0.162	0.436	4.064	<.001	2933.2	21	<.001	99.3
Agricultural dependence		10	-0.163	-0.232	-0.093	-4.538	<.001	84.2	9	<.001	89.3
Distance/accessibility		10	-0.104	-0.176	-0.030	-2.767	0.006	80.0	9	<.001	88.7
Physical capital		15	0.162	0.005	0.311	2.016	0.044	1035.0	14	<.001	98.6
Natural capital		14	0.219	0.022	0.400	2.171	0.030	707.9	13	<.001	98.2
Human capital		15	0.322	0.111	0.506	2.936	0.003	2064.3	14	<.001	99.3
Natural-disaster exposure		10	-0.126	-0.257	0.009	-1.828	0.068	302.5	9	<.001	97.0
Adaptive livelihood strategies		12	0.394	0.191	0.565	3.661	<.001	496.6	11	<.001	97.8

Note. r denotes the harmonized correlation-type association. Reported p values are two-sided and nominal; no multiplicity adjustment was applied. I^2 quantifies between-study inconsistency, not its source. Because contributing estimates include zero-order and adjusted associations, pooled magnitudes should not be interpreted as causal rankings.*

As shown in Figure 4 and summarized in Table 5, the small-study-effect diagnostics for the resilience syntheses provide no consistent asymmetry signal. Because the resilience evidence base is larger for many determinants, more Egger regressions meet the approximate ten-study threshold. None of these better-populated syntheses has a two-sided p value below 0.05. Natural capital is closest (k = 14, p = 0.052), followed by male-headed household status (k = 10, p = 0.066) and human capital (k = 15, p = 0.074). These near-threshold values do not establish publication bias, particularly under extreme heterogeneity. Tests based on fewer studies, including those for female-headed household status, health, and disaster experience, are not interpreted formally.

Taken together, Figures 3–4 and Tables 3–5 do not show a consistent small-study-effect signal, but the diagnostic coverage is uneven. Many vulnerability syntheses are too small for informative Egger tests, while extreme heterogeneity complicates funnel-plot interpretation even where k is larger. A non-significant Egger test therefore means only that asymmetry was not detected in that synthesis; it does not establish the absence of publication or selective-reporting bias.

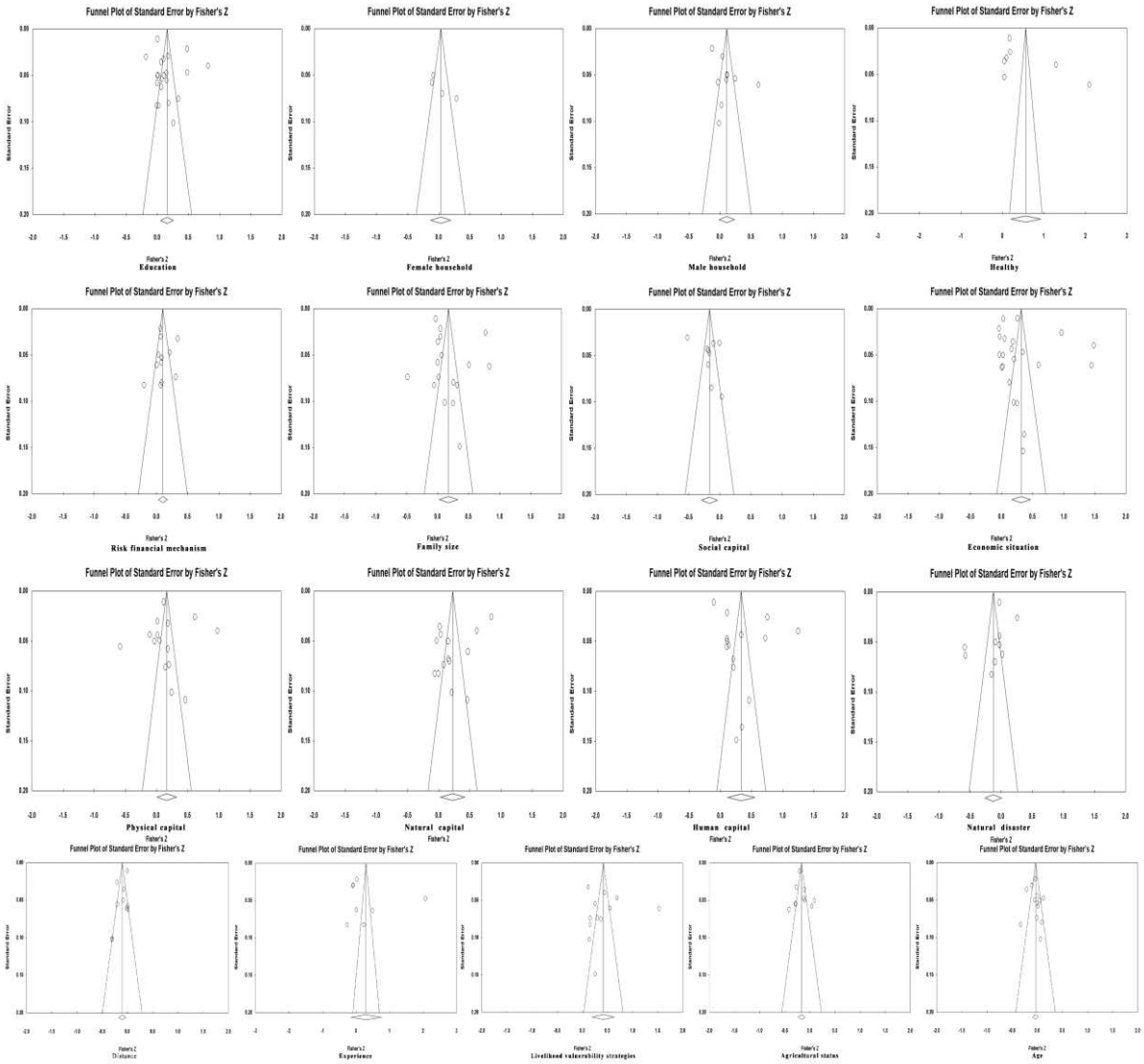


Figure 4. Funnel plots for small-study-effect diagnostics in rural resilience syntheses.

Table 5. Egger regression diagnostics for rural resilience syntheses.

Influencing factor		Intercept	SE	95% CI lower	95% CI upper	t	df	p (1-tailed)	p (2-tailed)
Education		2.41362	2.554	-2.932	7.759	0.945	19	0.178	0.356
Gender	Female	12.85655	5.09033	-9.04535	34.75845	2.526	2	0.064	0.12747
	Male	5.68561	2.667	-0.463	11.835	2.132	8	0.033	0.066

Influencing factor	Intercept	SE	95% CI lower	95% CI upper	t	df	p (1-tailed)	p (2-tailed)
Health	14.69689	10.683	-12.764	42.158	1.376	5	0.114	0.227
Age	1.01016	1.54479	-2.390	4.410	0.654	11	0.263	0.527
Risk financing	-0.55943	1.991	-4.996	3.877	0.281	10	0.392	0.784
Experience	10.42611	13.342	-22.222	43.074	0.781	6	0.232	0.464
Family size	3.32336	3.077	-3.234	9.881	1.080	15	0.149	0.297
Social capital	1.44329	3.22729	-5.28872	8.1753	0.44721	20	0.32976	0.65953
Economic conditions	4.073	3.880	-4.020	12.167	1.050	20	0.153	0.306
Agricultural dependence	1.14994	1.621	-2.587	4.887	0.710	8	0.249	0.498
Distance/accessibility	-2.28826	1.280	-5.240	0.664	1.787	8	0.056	0.112
Physical capital	0.329	3.807	-7.895	8.553	0.086	13	0.466	0.933
Natural capital	-9.523	4.412	-19.137	0.091	2.158	12	0.026	0.052
Human capital	8.695	4.481	-0.987	18.376	1.940	13	0.037	0.074
Natural-disaster exposure	-2.6673	2.780	-9.077	3.743	0.960	8	0.183	0.365
Adaptive livelihood strategies	1.75212	5.553	-10.621	14.125	0.316	10	0.379	0.759

Note. Egger regressions are treated only as small-study-effect diagnostics. Interpretation relies on two-sided p values and is especially limited when k is below about 10 or heterogeneity is high.

3.3 Assessment approaches and predisposing contexts

Six broad assessment approaches recur across the included literature. Index construction is the most frequently coded approach, with 23 occurrences, followed by statistical models with 17 and participatory evaluation with 12. Spatial analysis appears seven times, machine learning five times, and scenario simulation four times. Because individual studies can use more than one approach, these 68 occurrences are method uses rather than mutually exclusive study counts. Table 6 therefore describes a methodologically plural field that remains anchored in multidimensional indices and statistical modelling.

The approaches answer different questions. Composite indices such as the Climate Resilience Index and Livelihood Vulnerability Index summarize multiple dimensions of rural conditions, whereas regression-based models isolate associations between particular determinants and an outcome. Participatory approaches capture local perceptions and community knowledge that may be absent from secondary data. Spatial methods identify geographic concentrations and accessibility constraints, machine-learning applications accommodate potentially nonlinear relationships, and scenario simulations examine prospective responses to extreme events. These differences help explain why measures labelled “resilience” or “vulnerability” are not always directly comparable across studies.

Figure 5 links assessment approaches to the pressures motivating the studies. Climate change and climate-related hazards dominate the largest flows, while poverty, food insecurity, urbanization, marketization, water scarcity, health shocks, and other socioeconomic pressures form smaller streams. Resilience and vulnerability draw on overlapping methodological traditions rather than two separate literatures. The research landscape is therefore diverse in technique but comparatively concentrated in problem framing, with climate-related rural stress providing the dominant empirical context.

Table 6. Assessment methods used in the rural resilience/vulnerability evidence base.

Method category	Specific method	Number of coded uses	Representative study IDs	Primary analytical use
Index construction method	Climate Resilience Index (CRI), Livelihood Vulnerability Index (LVI-IIPCC)	23	4, 6, 10, 19, 39, 55	Multidimensional composite assessment
Statistical model	Principal Component Analysis (PCA), Ordered Logit Regression, Tobit Regression	17	5, 15, 34, 44, 54	Determinant estimation
Machine learning	Random Forest and Regression Tree Analysis	5	21, 25	Nonlinear prediction
Participatory evaluation	Questionnaire survey, community interview	12	7, 9, 23, 30, 47	Local perceptions and community knowledge
Scenario simulation	Land use model (LANDIS), disaster simulation	4	14, 15, 33	Scenario-based impact assessment
Spatial analysis	GIS spatial overlay and entropy method	7	32, 46	Spatial pattern and accessibility analysis

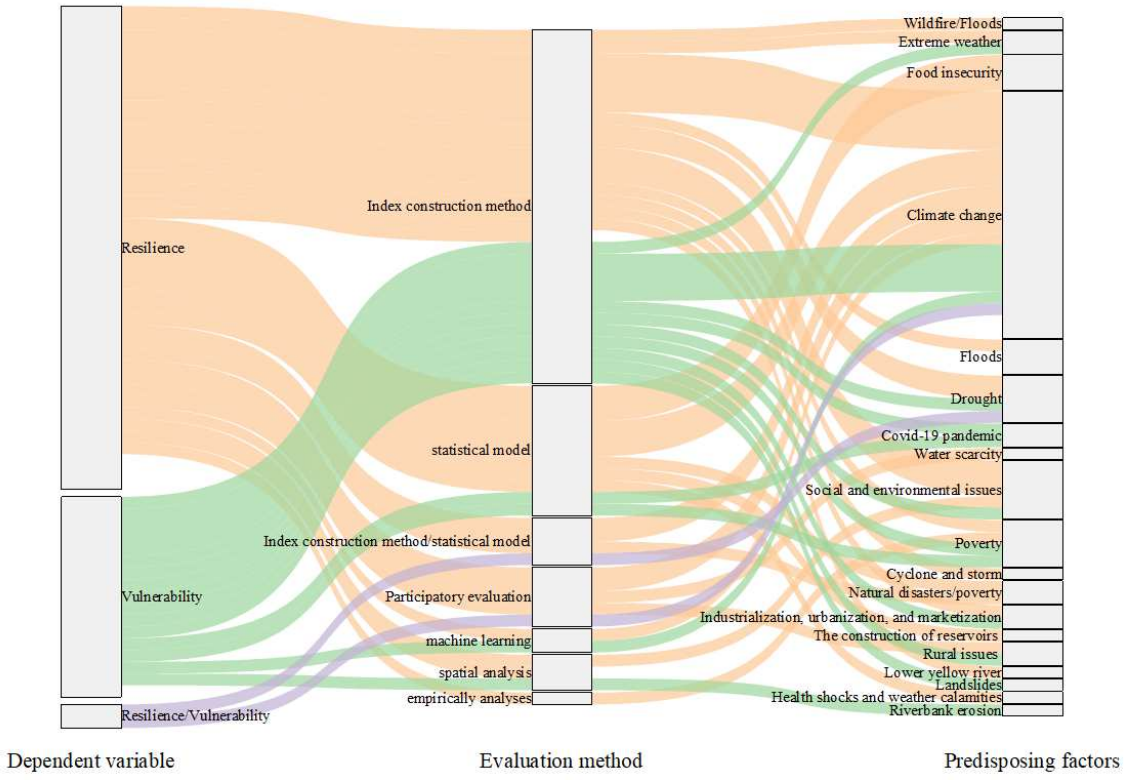


Figure 5. Relationships among outcome focus, assessment methods, and predisposing stressors.

4. Discussion

4.1 Interpreting shared capacity domains and structural constraints

We use shared capacity core as a compact description of the eight domains with concordant average directions across the two separate syntheses. It should not be read as evidence that these domains exert the same causal effect, or even operate through the same mechanism, in every setting. The value of the pattern is narrower: education, health, economic resources, social and physical capital, natural capital, adaptive livelihood strategies, and agricultural dependence repeatedly appear in the statistical structure of both outcomes. These domains are also plausibly interdependent. Health can affect the ability to work and learn; infrastructure can condition the returns to education and finance; and ecological conditions can expand or restrict livelihood choices. The meta-analysis does not estimate these complementarities directly, but the recurrent domains are consistent with multidimensional accounts of rural adaptive capacity and provide a more defensible synthesis than a rank ordering of isolated coefficients.

Agricultural dependence and accessibility point to a structural interpretation, but the mechanism is not identified by the pooled associations. The positive vulnerability association and negative resilience association for agricultural dependence may reflect concentration of climate, production, or price risk where households rely heavily on a narrow livelihood base; they could also reflect unmeasured differences in assets, markets, or exposure. Likewise, the negative resilience association for distance/accessibility is consistent with higher costs of reaching markets, water, services, and information, but the available synthesis cannot isolate which channel matters. The development implication is therefore to examine the opportunity structure around household resources rather than infer that farming, remoteness, or any single asset is intrinsically harmful or protective. Evidence from rural China similarly shows that livelihood differentiation and broader development can reduce flood sensitivity, while the benefits depend on household exposure and livelihood orientation (Tian & Lemos, 2018).

4.2 Cross-outcome divergence and heterogeneity

The descriptive cross-outcome divergence is consistent with the argument that vulnerability and resilience capture different parts of the risk process, but it does not prove that any determinant has a statistically different effect across outcomes. Natural-disaster exposure has a clearer pooled signal for vulnerability, while risk financing, family size, and broad human capital have clearer pooled signals for resilience; these differences may reflect outcome construction, study composition, or power as well as substantive mechanisms. The same caution applies to heterogeneity. Very high I^2 demonstrates inconsistency, not its cause.

Genuine contextual variation is plausible, but measurement choices, adjustment sets, sampling, and study design can also generate heterogeneity. Without effect-level moderator analysis or prediction intervals, the manuscript cannot decompose these sources. The strongest transferable conclusion is therefore that some capacity and structural domains recur, while the magnitude—and possibly even the direction—of an association in a new rural setting remains uncertain.

4.3 Implications for rural development policy

For rural development policy, the synthesis is best used to structure diagnosis rather than to select a universal intervention package. Health, skills, productive resources, social connections, ecological assets, livelihood options, and access recur often enough to warrant attention, but the meta-analysis does not estimate the effect of policies that change them. Where agricultural dependence reflects a lack of viable alternatives, credit need not improve resilience if profitable opportunities are absent; where access is the binding constraint, skills or finance may have limited returns without connectivity and services. The policy-relevant transfer is therefore functional rather than programmatic: identify which capacities or structural constraints are binding locally, examine the institutions and markets through which they operate, and then choose instruments whose effects can be evaluated in that setting. Recent evidence from Bangladesh further suggests that integrated rural development can strengthen several resilience capacities at once through income and assets, livelihood diversification, education, and social participation (Park & Ochieng, 2024).

4.4 Limitations and priorities for future synthesis

Two technical constraints qualify the present synthesis. First, zero-order correlations, regression-derived partial correlations, and z-based approximations can be harmonized numerically, but they do not become the same estimand when adjustment sets and model families differ. Second, p values are nominal across many syntheses at the determinant level, and no multiplicity correction was applied, although the synthesis is interpreted primarily through direction, confidence intervals, number of contributing studies, and heterogeneity rather than binary significance thresholds. These constraints delimit the precision of inference but do not alter the directional conclusions of the analysis.

Future synthesis should proceed in several directions. Rebuilding the dataset at the effect level, preregistering rules for selecting estimates, and retaining complete search histories would allow dependence within studies to be modeled more reliably. Where effects are dependent, multilevel or cluster robust methods should be used, and tau squared and prediction intervals

should be reported to better characterize the range expected in new settings. Prespecified moderators should be tested to identify which contextual, measurement, or design features systematically shape association strength, rather than attributing heterogeneity to random variation alone. A risk of bias appraisal appropriate to the design and better powered diagnostics for small studies are also needed. Beyond these methodological steps, future research should encourage more studies to measure both vulnerability and resilience, promote standardized measurement and model specification, and enable paired comparisons within the same populations. Analyses of moderators across contexts could further clarify which determinants matter most under which conditions, providing a stronger evidence base for locally grounded rural development policy. These priorities would move the field from a comparative synthesis toward a more explanatory and policy-relevant body of evidence.

5. Conclusion

Rural vulnerability and resilience are related but not empirically interchangeable. Across the 60-study evidence base, eight determinant domains show concordant average directions in the separate syntheses: education, health, social capital, economic conditions, physical capital, natural capital, adaptive livelihood strategies, and agricultural dependence. Other patterns diverge across the two evidence bases, but these differences are descriptive because only two studies report both outcomes and no formal between-outcome contrast can be reconstructed. The paired analysis therefore adds value by showing both recurrent domains and the limits of treating resilience as the inverse of vulnerability.

The findings do not support a universal ordering of determinants or a set of policy coefficients that can be transferred across settings. Very high heterogeneity, heterogeneous adjustment, and incomplete information on dependence mean that pooled r* values are best used to identify questions for local diagnosis. The recurrent domains indicate where evidence collection and policy appraisal may be most informative—health, skills, livelihood options, productive and ecological resources, social connections, and access—while local exposure, markets, institutions, infrastructure, and ecological conditions determine whether a particular intervention is appropriate.

Future synthesis should rebuild the effect-level dataset, preserve complete search and estimate-selection records, distinguish zero-order from adjusted associations, model dependent effects explicitly, report tau-squared and prediction intervals, test prespecified moderators when study numbers permit, and undertake design-appropriate risk-of-bias assessment. Until then, the

present study is best read as a comparative map of recurrent associations, descriptive cross-outcome divergence, and unresolved heterogeneity. Its strongest contribution is therefore a disciplined comparison of recurrent capacity and structural domains, cross-outcome divergence, and the limits of generalization in the current quantitative rural evidence base.

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Competing interests

The authors declare no competing interests.

Data availability

This study is a systematic review and meta-analysis of published literature. All supporting materials are available as follows: the PRISMA 2020 checklist and the PRISMA flow diagram are provided as Supplementary File S1; the documented search structure is provided as Supplementary Table S2; the complete record inventory (EndNote library export) and the 60 studies included in the final synthesis are provided as Supplementary File S3; and the data extraction template, the completed extraction dataset, and the synthesis tables are provided as Supplementary File S4.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

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