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Review

Crop diversification and climate resilience in farming and rural livelihood systems: Advances, challenges, and pathways for sustainable development

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Supplementary

Table S1. Study characteristics and roles of the 81 publications cited in this paper.

Reference	Design or source type	Location	Diversification or context	Outcomes assessed or focus	Class	Basis
[1] F. Terán et al. (2024)	Review	Multiple regions	Crop stress-management context	Abiotic stress and mitigation	C	A
[2] C. Folke (2016)	Conceptual synthesis	General	Not a diversification test	Resilience concepts	C	P
[3] R. Hajjar et al. (2008)	Review	Multiple regions	Within-crop genetic diversity	Ecosystem services	I	V
[4] C. Béné (2020)	Conceptual review	Multiple regions	Food-system context	Food security and shock response	C	V
[5] C. Folke et al. (2010)	Conceptual synthesis	General	Not a diversification test	Resilience, adaptability and transformability	C	V
[6] R. Vernooy (2022)	Literature review and theory development	Multiple regions	Crop and varietal diversification	Livelihood benefits and resilience pathways	C	V
[7] J. Hansen et al. (2019)	Review/synthesis	Multiple regions	Climate-risk-management context	Poverty and risk management	C	V
[8] D. Beillouin et al. (2019)	Evidence map	Global	Multiple diversification strategies	Agronomic and ecosystem outcomes	I	V
[9] R. Bezner Kerr et al. (2019)	Participatory agroecological intervention	Malawi	Legume diversification	Food security and dietary diversity	I	V
[10] W. Tesfaye and N. Tirivayi (2020)	Household panel analysis	Uganda	Crop portfolios	Welfare and consumption smoothing under risk	I	V
[11] T. Chapagain et al. (2018)	On-farm intercropping study	Nepal	Cereal and other crop intercrops	Land productivity and returns	I	V
[12] I. G. K. Ansah et al. (2019)	Conceptual and empirical review	Multiple regions	Contextual resilience source	Food security and resilience measurement	C	V
[13] J. D. B. Gil et al. (2017)	Review of statistical and modeling studies	Multiple regions	Integrated agricultural systems	Performance under climate variability; heterogeneous proxies	C	P/V
[14] M. Kozicka et al. (2024)	Program evaluation; design details not fully extracted	Ethiopia	On-farm agrobiodiversity	Safety-net participation and diversity	I	P

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Reference	Design or source type	Location	Diversification or context	Outcomes assessed or focus	Class	Basis
[15] M. Reckling et al. (2023)	Cross-scale synthesis	Multiple regions	Agricultural landscape diversification	Coordination across scales	C	P
[16] T. Choden et al. (2026)	Systematic review and meta-analysis	Temperate Northern Hemisphere	Silvoarable agroforestry	Biodiversity, yield and ecosystem services	I	A
[17] A. F. Ebbisa et al. (2024)	Randomized block field experiment, 2021–2022	Babile, Ethiopia	Sorghum–peanut rows and vermicompost	Component yields, system performance and profit	I	A
[18] M. Kozicka et al. (2020)	Multi-level analysis; design details not fully extracted	Uganda	Agrobiodiversity	Future regime shifts and farming options	C	V
[19] N. Chanana-Nag and P. K. Aggarwal (2020)	Gender and climate-risk synthesis	Multiple regions	Gender-related context	Exposure, constraints and inclusion	C	V
[20] B. B. Lin (2011)	Conceptual review	Multiple regions	Crop diversification	Adaptive management mechanisms	C	V
[21] J. Hufnagel, M. Reckling, and F. Ewert (2020)	Review	Multiple regions	Definitions and types of crop diversification	Research approaches and functional diversity	C	V
[22] D. I. Jarvis et al. (2011)	Heuristic framework and review	Multiple regions	Traditional crop varieties	Conservation and ecosystem functions	C	V
[23] P. F. McCord et al. (2015)	Smallholder livelihood study; design details not fully extracted	Mount Kenya region, Kenya	Crop portfolios	Diversification and livelihood strategies	I	V
[24] S. Asfaw, G. Pallante, and A. Palma (2018)	Empirical household analysis; design details not fully extracted	Niger	Livelihood diversification	Welfare and adaptation deficit	I	V
[25] FAO (2016)	Working paper; related to [31]	Zambia	Crop and livelihood diversification	Climate shocks and welfare	C	P/V
[26] G. Owen (2020)	Systematic review	Multiple regions	Adaptation context	Effectiveness of adaptation	C	V
[27] R. Vernooy and V. Vongkhamsao (2015)	Policy synthesis chapter	Cambodia, Lao PDR and Vietnam	Crop diversification	Policy measures and implementation	C	V
[28] T. Tanner et al. (2015)	Conceptual synthesis	Multiple regions	Livelihood context	Livelihood resilience	C	V
[29] C. A. Córdoba Vargas et al. (2020)	Conceptual discussion	Agroecological systems	Agroecology context	Political and other resilience dimensions	C	V

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Reference	Design or source type	Location	Diversification or context	Outcomes assessed or focus	Class	Basis
[30] C. Nelimor et al. (2019)	Experimental germplasm evaluation	Burkina Faso	Maize landrace diversity	Drought, heat and combined-stress tolerance	I	V
[31] A. Arslan et al. (2018)	Empirical climate-variability analysis; related report [25]	Zambia	Crop and livelihood diversification	Welfare under climatic variability	I	M
[32] S. Fraval et al. (2019)	Household-data analysis; design details not fully extracted	Sub-Saharan Africa	Agricultural-intervention context	Food-access deficiencies	I	V
[33] B. K. Joshi et al. (2020)	Practice synthesis chapter	Nepal	Cultivar mixtures	Risk management and conservation	C	V
[34] B. Lal et al. (2017)	Field cropping-system comparison	Eastern India	Rice varieties and additional pulse/oilseed crops	System productivity and profitability	I	V
[35] R. Nankya et al. (2017)	Farmer adoption and yield-perception analysis	Uganda	Bean and banana varietal mixtures	Yield perceptions, adoption and disease-related benefits	I	V
[36] G. Tamburini et al. (2020)	Quantitative synthesis	Global	Multiple agricultural diversification practices	Ecosystem services and mean yield	I	V
[37] S. Attwood et al. (2017)	Synthesis chapter	Multiple regions	Agrobiodiversity	Multiple ecosystem services	C	V
[38] A. C. M. Gaudin et al. (2015)	Long-term cropping experiment	Ontario, Canada	Diverse crop rotations	Yield stability under characterized weather conditions	D	V
[39] M. Raseduzzaman and E. S. Jensen (2017)	Meta-analysis	Multiple regions	Intercropping	Yield stability	I	V
[40] M. S. Islam et al. (2024)	Survey of 122 farmers; Tobit and log-linear models	Rangpur, Bangladesh	Simpson crop-diversity index	Adoption factors and farm income	I	A
[41] J. D. Michler and A. L. Josephson (2017)	Household panel analysis	Ethiopia	Agricultural diversity	Poverty dynamics	I	V
[42] N. Mango et al. (2018)	Observational household study	Central Malawi	Crop diversification	Household food security	I	V
[43] C. Makate et al. (2016)	Observational smallholder analysis	Zimbabwe	Crop diversification	Crop income, productivity and food security	I	V
[44] J. Ochieng et al. (2020)	Empirical climate-risk analysis; design details not fully extracted	Rural Kenya	Crop diversification	Climate-related income risk	I	V

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Reference	Design or source type	Location	Diversification or context	Outcomes assessed or focus	Class	Basis
[45] K. Waha et al. (2018)	Multi-scale analysis	Africa	Agricultural production diversity	Food security and diversification potential	I	V
[46] D. Feliciano (2019)	Review	Multiple regions	Crop diversification	Poverty outcomes	I	V
[47] G. Danso-Abbeam (2025)	GLSS 7 survey; hurdle and bivariate probit models	Ghana	Crop diversification	Multidimensional poverty	I	A
[48] G. Danso-Abbeam et al. (2023)	Household welfare analysis; design details not fully extracted	Northern Ghana	Perennial crop production	Income and food expenditure	I	M
[49] G. Meldrum, A. Sidibe, and S. Padulosì (2020)	Project report	Mali	Bambara groundnut, fonio and native vegetables	Nutrition and crop-use opportunities	C	V
[50] F. Rampa and H. Knaepen (2019)	Policy and value-chain report	Southern Nakuru, Kenya	Indigenous vegetables	Markets and sustainable food-system pathways	C	V
[51] S. K. Ng'ang'a et al. (2016)	Empirical adaptation study; design details not fully extracted	Borena, Ethiopia	Agricultural adaptation and diversification	Adaptation options under climate stress	C	V
[52] T. T. Duong et al. (2019)	Global review	Global	Risk-management context	Farmer perceptions and strategies	C	V
[53] T. Wegenast et al. (2024)	Matched difference-in-differences using household panel and weather data	Tanzania	Traditional diversification practices	Food consumption and coping during extreme weather	D	A/P
[54] J. Garbole, G. Dima, and D. Kanchora (2025)	Survey and key informant interviews; 381 households	Dubluk, Borana, Ethiopia	Crop–livestock and livelihood diversification	Diversification decisions and food-security association	I	A
[55] S. L. Dwivedi et al. (2017)	Review	Multiple regions	Food-system diversification	Sustainable production and diets	C	V
[56] A. De Pinto, M. M. Islam, and P. Katic (2023)	Synthesis chapter	Multiple regions	Food-security context	Integration of resilience in research and practice	C	M
[57] R. U. Onyeneke et al. (2019)	Systematic review	Nigeria	Agricultural adaptation measures	Adaptation and resilience dimensions	C	V
[58] G. Meldrum et al. (2018)	Farmer-perception and adaptation study	Bolivian Altiplano	Potato, quinoa and crop portfolios	Perceived climate risks and adaptation trade-offs	I	V

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Reference	Design or source type	Location	Diversification or context	Outcomes assessed or focus	Class	Basis
[59] C. Hotz et al. (2012)	Randomized controlled effectiveness intervention	Rural Mozambique	Orange-fleshed sweet potato production and consumption	Vitamin A intake among children and women	I	P
[60] T. Mabhaudhi et al. (2019)	Review	Multiple regions	Underutilized crops	Nutritional and stress-tolerance potential	C	V
[61] W. S. de Boef et al. (2013)	Edited volume of approaches and cases	Multiple regions	Community biodiversity management	Conservation, learning and institutions	C	V
[62] F. Dapilah, J. Ø. Nielsen, and C. Friis (2020)	Social-network case study	Northern Ghana	Social organization context	Adaptive capacity and resilience	C	P/V
[63] E. A. Frison, J. Cherfas, and T. Hodgkin (2011)	Conceptual review	Multiple regions	Agricultural biodiversity	Nutrition and food-security pathways	C	V
[64] A. De Pinto et al. (2020)	Empirical household analysis	Bangladesh	Farmland allocation and crop diversification	Women's empowerment and crop decisions	I	V
[65] T. W. Reynolds et al. (2020)	Comparative household analysis	Kenya, Tanzania and Uganda	Crop selection and use	Gendered resource constraints and crop values	I	V
[66] J. W. Hansen et al. (2019)	Climate-services synthesis	Africa	Context-specific adaptation options	Information and adaptive capacity	C	M
[67] C. Ragasa et al. (2021)	Cluster-randomized nutrition-education trial	Central Dry Zone, Myanmar	Contextual nutrition intervention	Diet quality during COVID-19; not a diversification test	C	M
[68] D. Amoak and D. Najjar (2026)	Scoping review of 47 studies	Global South	Agrifood governance context	Gender barriers and enabling interventions	C	A
[69] C. W. Rubiyanto and W. Susanti (2024)	Interviews, focus group and yield observation; nine respondents	Gunungkidul, Indonesia	Traditional intercropping	Cultivation practices and livelihood context	I	A
[70] E. K. Burchfield and A. T. D. L. Poterie (2018)	Empirical adoption study; design details not fully extracted	Sri Lanka	Diversification in rice systems	Determinants of diversification	C	V
[71] S. McGuire and L. Sperling (2013)	Seed-system analysis and synthesis	Multiple regions	Seed-system diversity	Access and functioning under stress	C	V
[72] G. Danso-Abbeam et al. (2018)	Empirical extension evaluation; design details not fully extracted	Northern Ghana	Extension context	Farm productivity and income	I	M

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Reference	Design or source type	Location	Diversification or context	Outcomes assessed or focus	Class	Basis
[73] S. Di Falco, M. Bezabih, and M. Yesuf (2010)	Empirical production analysis; design details not fully extracted	Ethiopia	Crop biodiversity	Food production and seed-related conditions	I	V
[74] IPBES (2019)	Intergovernmental assessment summary	Global	Biodiversity context	Ecosystem services and policy	C	P
[75] E. R. Till et al. (2024)	Research-agenda book	Multiple settings	Agricultural transformation context	Political leadership and transformation	C	M
[76] J. Panda and G. S. Parashari (2024)	District-level composite-index analysis	Odisha, India	Agricultural-system context	Agricultural resilience and spatial heterogeneity	I	A
[77] U. Das, S. Ghosh, and B. Mondal (2020)	District-level index and adaptation analysis	Odisha, India	Agricultural-system context	Agricultural conditions and resilience	I	P
[78] M. van Zonneveld et al. (2020)	Decision-making framework/synthesis	Multiple regions	Farm-system diversification	Adaptation planning and choices	C	V
[79] J. Wichern et al. (2019)	Country-wide livelihood analysis	Uganda	Livelihood and farming options	Vulnerability and adaptation options	C	V
[80] M. A. Altieri et al. (2015)	Agroecological synthesis	Multiple regions	Diversified farming systems	Climate-resilience mechanisms and design	C	V
[81] E. M. Njeru (2013)	Conceptual synthesis	Sub-Saharan Africa	Smallholder crop diversification	Food-security pathways	C	V

This inventory covers the complete reference list, including empirical outcome studies, reviews, conceptual contributions and contextual sources. Reference numbers correspond to the manuscript. It is a source-level inventory, not a PRISMA inclusion list or a count of independent studies. Reviews may overlap with primary studies; [25] and [31] are related reports and should not be counted as independent evidence.

D = direct, disturbance-linked evidence; I = indirect/proxy evidence; C = conceptual/contextual use in this review. Categories describe the source's use for the diversification-to-resilience pathway, not its overall quality. A nutrition intervention can therefore be I despite an experimental design. "Not fully extracted" identifies unavailable detail rather than a confirmed absence of that method.

Basis codes: V = study characterization available in Vernooy [6]; A = supplied Scopus abstract; P = publisher or institutional primary-source record consulted; M = manuscript bibliography and narrative only, with no claim of fresh full-text extraction. Multiple codes indicate complementary information. The Scopus export is dated 25 September 2025 and includes records assigned to 2026 issues; that date is not used as the review's search-completion date.