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Livelihood Resilience among Coffee Smallholders in East Java, Indonesia: Diversification, Resource Adequacy and Perceived Income Stability

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Abstract

Diversification is often assumed to strengthen livelihood resilience, yet its apparent benefits may depend on the resources available to households. This study examines how perceived water and soil resource adequacy, the intensity of diversification practices, and external institutional support are associated with perceived income stability under extreme weather conditions among coffee smallholders. Data were obtained from 156 questionnaires administered to coffee-growing households in Dampit, Wajak, and the Arjuno–Welirang slopes of East Java, Indonesia, in April and May 2025 using purposive, nonprobability sampling. Perceived income stability was measured as the mean of three items assessing income sources, production costs, and income changes under extreme weather conditions. Exploratory ordinary least squares regression models with robust standard errors were estimated to compare linear and categorical specifications of resource adequacy, interaction and quadratic terms, and household-level covariates. Perceived income stability exhibited an inverted U-shaped pattern across four observed resource adequacy categories, with mean scores of 1.31, 2.20, 3.02, and 2.40, respectively. Modeling resource adequacy categorically increased the explained variance from 0.30 to 0.62. The association between diversification intensity and perceived income stability varied across model specifications but became statistically insignificant when resource adequacy was modeled categorically. Institutional support was consistently negatively associated with perceived income stability, although this finding should not be interpreted causally. These findings suggest that resource adequacy may account for apparent associations between diversification and perceived income stability, while diversification practice counts alone provide limited evidence of broader livelihood resilience. Given the exploratory, perception-based, and cross-sectional design, the results warrant cautious interpretation and further longitudinal investigation.

INTRODUCTION

Most Indonesian coffee is produced on smallholdings of one to two hectares, and coffee cultivation serves as a primary source of cash income for the households managing these farms

(BPS-Statistics Indonesia, 2024). In East Java, coffee is predominantly cultivated on steep volcanic slopes, where productivity depends on rainfall distribution during flowering, water availability throughout the dry season, soil depth in erosion-prone areas, and favorable weather conditions during harvesting. Research conducted in other coffee-producing regions demonstrates how these environmental and economic pressures directly affect rural households, as weather-related hazards, pest infestations, and low market prices collectively contribute to income instability and food insecurity (Rodriguez-Camayo et al., 2025). Previous research on Indonesian coffee production has primarily focused on value chains, certification schemes, and buyer-led programs, whose benefits are unevenly distributed among farming households (Vicol et al., 2018). However, relatively little is known about the factors associated with maintaining farm income stability when extreme weather constitutes the primary source of disruption.

Diversification is the usual answer. Adding crops, trees and animals to a coffee farm is expected to lower exposure to yield and price swings, return nutrients to the soil, reduce bought inputs and create further income sources (Bracken et al., 2023; Duffy et al., 2021; Poncet et al., 2024). Studies of diversified farming systems under climate-sensitive conditions report improved soil function, higher profit and lower risk (Assefa et al., 2021; Harkness et al., 2021; Kumari et al., 2024; Sun et al., 2025), and a systematic review ranks it among the farm-level responses to climate stress most often documented in low-income countries (Mohamed Shaffril et al., 2024). Livelihood researchers have been warier. Ellis (2000) separated opportunity-led from necessity-led diversification, and later reviews distinguish progressive from distress diversification: households sometimes take up low-return activities because better ones are out of reach (Habib et al., 2023; Rubiyanto & Hirota, 2021). In Chiapas, what a coffee farm diversified into counted for more than how much it diversified (Anderzén et al., 2020). Panel data from Malawi and Tanzania show diversification rising after rainfall shocks, and effective post-shock diversification clustering among better-endowed households (Makate et al., 2023). Measured diversification can thus signal exposure as easily as it signals a remedy.

The sustainable livelihoods framework gives a way to handle this ambiguity. It distinguishes the assets a household holds from the strategies it follows, and sees outcomes as the combined product of the two inside an institutional context (Scoones, 1998; Habib et al., 2023). Many composite indicators of agroecological adaptation mix the two, pairing practices such as growing non-coffee crops or recycling processing residues with ratings of water and soil. That is a problem if access to resources decides which practices are feasible and also relates to livelihood outcomes on its own, because a positive coefficient on the composite cannot say which part is doing the work. Two further gaps stand out. Socioeconomic and resilience outcomes are under-represented in coffee diversification research compared with biodiversity and ecosystem services (Teixeira et al., 2022). And external support is normally judged by whether farmers have access to it or take part, not by whether it reaches households that were already less secure (Trejo-Pech et al., 2023). Recent work on the coffee sector likewise distinguishes programmes that safeguard commodity supply from programmes that build household livelihoods (Grabs et al., 2026).

This study asks a rural-development question. Does more on-farm diversification go with greater perceived economic security, or does the answer depend on the resources a farmer can call on? Using 156 coffee households from Dampit, Wajak and the Arjuno–Welirang slopes of East Java, the analysis relates the intensity of diversification, the perceived adequacy of water and soil and the reported external institutional support to the security of income sources, production costs and income change in extreme weather. Particular attention goes to the functional form of the resource rating, because a rating that is related non-monotonically to the outcome can distort the coefficients of practices that correlate with it. The analysis is exploratory. It treats perceived income stability under extreme weather as one outcome dimension of livelihood resilience, that is, of a household's capacity to keep its income going under stress, and makes no claim to measure resilience as a whole or to estimate the causal effect of any programme.

The objective of this study is therefore to examine how perceived water and soil adequacy, diversification practice intensity and external institutional support relate to perceived income stability under extreme weather, and whether the shape of the resource rating changes what the practice coefficient appears to show.

The study contributes in three ways. First, it applies the livelihoods distinction between assets and strategies to coffee households by keeping perceived water and soil adequacy apart from diversification practices instead of combining them in one index. Second, it shows that the functional form of a single resource rating can change the sign and the apparent conditionality of the practice coefficient. Third, it reports how institutional support relates to perceived stability net of both, in a setting where support was reported as largely absent. All three contributions are exploratory and rest on perception data, and none supports a causal claim.

The outcome is perceived income stability under climatic stress. It is treated as one bounded outcome dimension of livelihood resilience, the capacity to keep income going under stress, and not as a measure of resilience as a whole. It records how respondents judge the continuity of their income sources, the behaviour of production costs and the direction of income in extreme weather. It does not capture observed income variance, recovery from a dated shock, adaptive capacity or the household's resilience overall. Nor does it describe landholding, financial capital, output or the level of earnings. The distinction matters for policy because protecting commodity supply and securing household livelihoods are different goals (Grabs et al., 2026), and a favourable perception does not show that a household is objectively more resilient.

Following the livelihoods framework (Scoones, 1998; Habib et al., 2023) the analysis separates what a household can access from what it does. Perceived adequacy of water and soil stands for the resource context; it is a rating and not a measurement of natural capital. The number of non-coffee plant types and the use of coffee waste are two practices carried out within that context. The line is analytical, since agroforestry practices can themselves change resource conditions (Bracken et al., 2023; Khoirunnisak et al., 2023). The first hypothesis concerns resource adequacy and stability, and Figure 1 summarises the framework and the three hypotheses.

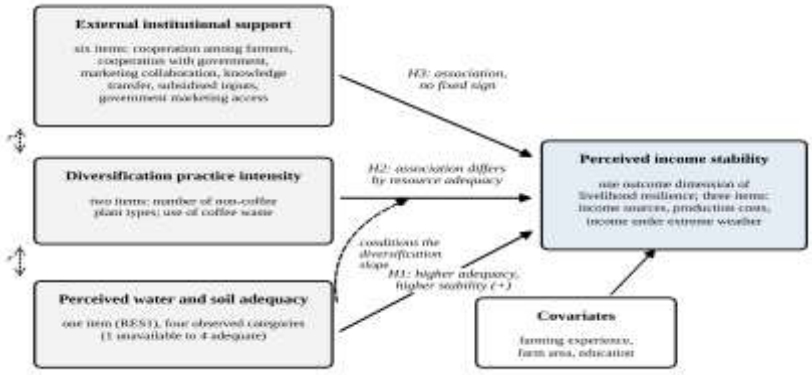


Figure 1. Conceptual framework. Solid arrows show the hypothesised associations between each predictor and perceived income stability; the dashed arrow shows that resource adequacy is expected to condition the association of diversification with stability; dotted double-headed arrows mark correlated predictors. All relations are associations in cross-sectional data, not causal paths.

H1. Higher perceived adequacy of water and soil is associated with higher perceived income stability.

For practice, two readings compete. The common one says that more diversification spreads risk and steadies cash flow (Arndt & Helming, 2025; Bracken et al., 2023). The other begins with the contrast between diversification that accumulates and diversification forced by necessity (Ellis, 2000; Rubiyanto & Hirota, 2021). On that view, households whose coffee income is unreliable add crops and animals since coffee alone does not cover their needs, and on small plots the additions draw labour, attention and land away from coffee. What a household can diversify into also depends on the resources and labour it has (Revoyron et al., 2022; Zhang et al., 2022). If resources condition both what households do and how stable they feel, the association between practice and stability may differ with resource adequacy, and its sign cannot be fixed in advance.

H2. The association between diversification practice intensity and perceived income stability differs by level of resource adequacy.

External institutional support covers government assistance and collaborative arrangements. In the study area extension, subsidies, farmer groups and buyer partnerships run through the same channels, so the two are treated as one domain (see Measurement Decisions in the Method section). Support can make practices easier by lowering information, input and market barriers, and it can strengthen the resource base through irrigation, soil conservation and seedling schemes. How it relates to outcomes also depends on who receives it. Where programmes aim at households judged to be in need, support will be found mostly among the less secure and the cross-sectional association turns negative because of allocation, not effect (Trejo-Pech et al., 2023). Where better-placed households capture the programmes, the sign reverses (Vicol et al., 2018). The association is therefore left without a sign.

H3. After diversification and resource adequacy are held constant, external institutional support is associated with perceived income stability.

METHOD

Research Design

This study employed a cross-sectional, exploratory household survey design. Data were collected through face-to-face interviews with purposively selected coffee-farming households. Ordinary least squares regression with heteroskedasticity-robust standard errors was used to examine the associations between perceived income stability under extreme weather conditions, diversification practice intensity, perceived water and soil resource adequacy, and external institutional support. The analysis was limited to associations within the surveyed sample and did not establish causal relationships or support population-level generalizations.

Study Area and Sample

The study took place in the coffee uplands of East Java, on the slopes of Mount Semeru and Mount Arjuno. Coffee there is mixed with other crops, shade trees and animals rather than grown alone, and much of the land is used under arrangements with the state forestry authority. Farmers describe problems with flowering, fruit set, drying, water supply and income. Robusta (Coffea canephora) and Arabica (Coffea arabica) are both cultivated. Questionnaires were collected in Dampit and Wajak sub-districts and on the Arjuno–Welirang slopes (mainly Karangploso sub-district) of Malang Regency and neighbouring areas. Mount Kawi was visited for observation only and contributed no questionnaires; a few farmers there acted as informants for the field notes. Six sets of written field notes, made between February 2024 and February 2026, describe rain-related production problems, water constraints, shade, the use of manure and coffee husk, intercropping, forms of sale and group arrangements. They serve only to illustrate conditions represented in the analysis. The analysis sample is 156 complete questionnaires from the first survey wave of a larger programme on coffee smallholders and climate-related livelihoods, collected face to face between 16 April and 20 May 2025. Areas were chosen purposively. Villages were identified with the help of village heads and farmer-group leaders, and individual farmers were included if they were adults actively managing a coffee plot and had experience of the practices and constraints covered by the questionnaire. Recruitment was therefore not random. The data support tests of association among coffee households in the surveyed uplands, not statements about all coffee farmers in East Java, and the coefficients are not population parameters. Enumerators interviewed respondents in Indonesian; the English wording in Table 2 comes from the English version of the instrument. Participation was voluntary; respondents consented before interviews began, and answers were anonymised before analysis. The same programme supplies data for other analyses by the research group, which address farm-business capacity as the outcome and use different constructs and a different model; the present study differs in its outcome, its construct structure and its analytical approach. The analysis file holds 156 rows and no missing cells. Its twelve indicator columns match the original indicator workbook value for value and in row order. Because the outcomes are self-reported perceptions, the file was also screened for patterned responding. Across all 39 ordinal items the mean absolute Spearman correlation was 0.21. One of the 741 item pairs exceeded 0.80 (maximum 0.84), no two respondents gave the same answer vector, and no respondent gave the same answer to every item.

The screen gave no sign of the halo pattern found in a different dataset from the wider programme, which is not used here. The instrument was designed for a larger programme on the social-ecological resilience of coffee farmers in Indonesia. It has a demographic section and 40 attitude and practice items in seven blocks. Twelve items were selected on conceptual grounds from four blocks (ecological diversity, collaboration management, institutional support and income instability; three items each). The blocks on income diversification, yield variability and natural-resource loss deal with income composition and biophysical damage and not with the question of practice versus endowment, so they were left out. Every item has five ordered categories with its own verbal anchors (Table 2). Scales were built as unweighted item means: external institutional support from six items (Cronbach's alpha 0.88), diversification practice intensity from two items (the number of non-coffee plant types and the use of coffee waste; inter-item correlation 0.45, alpha 0.61) and perceived income stability from three items (alpha 0.81). Perceived water and soil adequacy is a single item (RES1). Two features of this set need to be stated. First, the three stability items are tied to extreme weather. The outcome is therefore income continuity under stress and not general satisfaction with income, and it says nothing about profitability. Second, RES1 was printed in the questionnaire with its anchors in reverse order and was re-scored so that higher values mean greater adequacy, as for all other items. After re-scoring, it correlates positively with each stability item ($r = 0.469$, 0.321 and 0.257), with the stability score ($r = 0.417$) and with diversification ($r = 0.542$). Its response distribution was also consistent with the same item in the wider survey programme. These checks fit the stated orientation but do not prove it, and the coding could not be compared with the printed questionnaire. RES1 asks about water and soil in one question. Single items are defensible for concrete attributes (Diamantopoulos et al., 2012), yet this item spans two resource dimensions and has no reliability estimate. Water cannot be separated from soil or access from perceived quality, and the shared source of the ratings may inflate its link to the self-reported outcome. Responses covered four of its five categories: nobody chose 'very adequate'.

Instruments and Operationalization

Analysis Strategy

Perceived income stability, standardised to zero mean and unit variance, was regressed on the support and diversification scales and on resource adequacy by ordinary least squares. Coefficients are therefore expressed in standard deviations of stability per standard deviation of a scale, or, for resource categories, as differences from the lowest category. Standard errors are heteroskedasticity-robust (HC3; MacKinnon & White, 1985; Long & Ervin, 2000) with p-values from the normal reference distribution. Percentile 95% confidence intervals for key coefficients came from 5,000 case-bootstrap resamples (seed 20261104). In each resample all predictors, including their standardisation, were recomputed, and the bootstrap means agreed with the full-sample estimates. The models were built in steps. Models 1 and 2 enter resource adequacy as a linear term, without and with covariates. Model 3 enters adequacy as three dummy variables relative to the lowest observed category, without covariates, and Model 4 adds covariates. Eight dummy variables served as covariates: farming experience (five bands, lowest as reference), farm

area (four bands, smallest as reference) and education above primary school (33 households against 123). Farm-area codes were treated as categories and not as hectares because the interval labels differ between survey versions. Age and survey area were recorded in the survey programme but were not part of the linked analysis file used for this study, so they could not be entered as covariates. Interaction and curvature were examined in three ways, each with covariates: a product of diversification and the centred adequacy rating (Model 5), the same model with a quadratic adequacy term (Model 6) and a Wald test of diversification-by-category terms (Model 7). Within each category the association between diversification and stability was also checked by rank correlation. Collinearity was assessed by variance inflation factors and influential cases by Cook's distance. Point estimates were checked against a second least-squares routine. The category-based specifications were introduced after inspecting stability across the adequacy categories, so the analysis is exploratory and its specification search is itself a limitation (Vaithilingam et al., 2024). All computations used Python (NumPy and SciPy). Two measurement decisions rest on a preliminary latent-variable analysis of the original instrument, estimated by partial least squares (Table 3). In that analysis the collaboration and government-assistance blocks were not empirically distinct (heterotrait–monotrait ratio 0.943, 95% CI 0.836 to 1.053; 0.916 after removing the item on cooperation with government), so the six items were combined into one support scale. A diversification composite that included the water and soil item also behaved unevenly, because the three indicators correlated with stability at −0.08 (non-coffee plants), 0.06 (coffee-waste use) and 0.45 (water and soil). In the same analysis the diversification path to stability was 0.395 ($p < 0.001$) with all three indicators, but its bias-corrected interval ran from −0.082 to 0.521, and with the water and soil item removed it fell to 0.220 ($p = 0.330$). Model fit was also weak, with a standardised root mean square residual of 0.111 under the common-factor and 0.104 under the composite convention, above the conventional limit of 0.08. The water and soil rating was therefore kept apart from the two practice items. Both decisions were made after inspecting the same data, so the final specification cannot be read as independent confirmation of the original instrument (Sarstedt et al., 2019), and the hypotheses were not pre-registered or tested on a separate sample.

Measurement Decisions

Table 3. Preliminary latent-variable diagnostics that motivated the measurement decisions.

Diagnostic or path	Value	Assessment
HTMT: collaborative action – government assistance	0.943 (95% CI 0.836, 1.053)	Interval includes unity; blocks combined
HTMT after removing cooperation with government	0.916	Still not distinct
Correlation of diversification indicators with stability score	−0.081; 0.063; 0.445	Association carried by the water and soil item; item kept apart
Diversification → stability, all three indicators	0.395 ($p < 0.001$); BCa CI −0.082 to 0.521	Not robust to bias correction

Diagnostic or path	Value	Assessment
Diversification → stability, water and soil item removed	0.220 (p = 0.330)	Not significant
SRMR	0.111 (common-factor); 0.104 (composite)	Above 0.08 under both conventions

Note: HTMT, heterotrait–monotrait ratio; BCa, bias-corrected and accelerated bootstrap interval (10,000 subsamples); SRMR, standardised root mean square residual. These results come from the first specification of the original instrument, estimated by partial least squares, and are reported only to document why the six support items were combined and the water and soil item was kept separate. Source: own survey and estimation.

RESULTS AND DISCUSSION

Sample Profile

Diversification was already part of these farming systems (Table 4). Only 24% of respondents grew coffee alone, and 76% had at least one other plant type. Livestock was kept by 55%. Coffee income sat mostly in the lower bands: 35% earned less than IDR 5,000,000 (USD 303) a year from coffee and 12% more than IDR 40,000,000 (USD 2,424). Income from outside coffee was smaller still, with 69% under IDR 5,000,000. Participation in additional activities was common, but the low non-coffee income says it should not be read as evidence of strong returns. Institutional support was largely absent (Table 2): item means ranged from 1.39 to 1.64 on the five-point scale, and between 58% and 74% of respondents answered ‘never’ on each of the six support items.

Table 4. Profile of surveyed coffee farm households (n = 156).

Characteristic	Category (IDR)	Category (USD)	Respondents	Percentage (%)
Non-coffee plant types	None (coffee only)	–	37	24
	1 type	–	52	33
	2–3 types	–	30	19
	4 types	–	32	21
	>4 types	–	5	3
Livestock capacity	No livestock	–	70	45
	1 head of cattle	–	29	19
	2 head of cattle	–	23	15
	3–4 head of cattle	–	9	6
	>4 head of cattle	–	25	16
Coffee income per year	<5,000,000	<303	55	35
	5,000,000–10,000,000	303–606	34	22
	10,000,000–20,000,000	606–1,212	23	15

Characteristic	Category (IDR)	Category (USD)	Respondents	Percentage (%)
Non-coffee income per year	20,000,000–40,000,000	1,212–2,424	25	16
	>40,000,000	>2,424	19	12
	<5,000,000	<303	108	69
	5,000,000–10,000,000	303–606	30	19
	10,000,000–20,000,000	606–1,212	8	5
	20,000,000–40,000,000	1,212–2,424	7	4
	>40,000,000	>2,424	3	2

Note: Income figures are respondent-reported annual averages. Rupiah amounts were converted at IDR 16,500 per USD. Income bands are upper-bound exclusive. Plant-type categories follow the DIV1 item (n = 156; percentages rounded). Source: own survey and estimation.

Scales and Zero-Order Associations

Internal consistency was acceptable for the support (alpha 0.88; corrected item–total correlations 0.61 to 0.74) and stability scales (alpha 0.81; 0.63 to 0.68) and modest for the two-item diversification scale (alpha 0.61). Table 5 gives the correlations. Resource adequacy correlated positively with stability (r = 0.42) and strongly with diversification (r = 0.54) and moderately with support (r = 0.33). Diversification was essentially uncorrelated with stability (r = −0.04), and support had a small negative correlation with it (r = −0.10). Variance inflation factors in the additive models ranged from 1.25 to 1.58.

Table 5. Scale properties and zero-order correlations.

Scale	Items	Alpha	Mean (SD)	1	2	3	4
1. External institutional support	6	0.88	1.51 (0.68)	–	0.52	0.45	−0.14
2. Diversification practice intensity	2	0.61	2.32 (1.14)	0.43	–	0.58	−0.19
3. Perceived water and soil adequacy (RES1)	1	–	2.96 (0.96)	0.33	0.54	–	0.14
4. Perceived income stability	3	0.81	2.52 (0.71)	−0.10	−0.04	0.42	–

Note: Scales are unweighted item means on the 1–5 scoring. Below the diagonal, Pearson correlations; above the diagonal, Spearman rank correlations. The rank correlation between resource adequacy and stability (0.14) is much lower than the Pearson correlation (0.42) because the relation is not monotone (Figure 2). Source: own survey and estimation.

Stability across Resource-Adequacy Categories

Mean stability did not rise steadily with perceived resource adequacy (Figure 2a). It was 1.31 among the 18 households that rated water and soil as unavailable, 2.20 among the 20 that called them inadequate, 3.02 among the 68 that called them sufficient and 2.40 among the 50 that called them adequate. The step from 'sufficient' to 'adequate' goes down. The categories also differed in practice: households in the highest category were far more diversified (mean 3.53) than those in the other three (1.56 to 2.12; Figure 2b), and they reported more support (mean 1.88 against 1.19 to 1.40). Resource adequacy, diversification and support are thus entangled across categories, which sets up the problem for any linear specification.

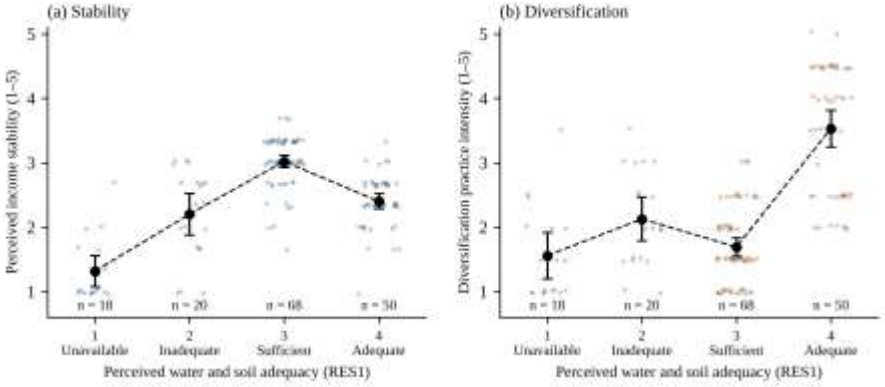


Figure 2. Perceived income stability (a) and diversification practice intensity (b) by category of perceived water and soil adequacy. Large dots are category means with 95% confidence intervals, dashed lines connect the means, and small dots are individual households (jittered). No household chose category 5, 'very adequate'.

Linear and Category-Based Regressions

With a linear resource term and no controls (Model 1, Table 6), resource adequacy was positively associated with stability ($\beta = 0.65$, $p < 0.001$; percentile 95% CI from Model 2 0.51 to 0.87), diversification negatively ($\beta = -0.32$, $p < 0.001$) and support negatively ($\beta = -0.18$, $p = 0.038$); $R^2 = 0.30$. Adding covariates (Model 2) weakened the diversification coefficient to −0.21 ($p = 0.015$; 95% CI −0.39 to −0.04), left the resource coefficient at 0.69 and the support coefficient at −0.18, and raised R^2 to 0.40 (adjusted 0.35).

Entering resource adequacy as categories changed the picture (Models 3 and 4). Relative to the lowest category, households in the second, third and fourth categories sat 1.16, 2.45 and 1.46 standard deviations of stability higher (Model 4; robust standard errors 0.32, 0.20 and 0.33; all $p < 0.001$). R^2 rose to 0.62 without and 0.65 with covariates, against 0.30 and 0.40 under the linear term. The diversification coefficient was no longer negative: it was 0.16 ($p = 0.086$) without and 0.11 (95% CI −0.08 to 0.28; $p = 0.22$) with covariates. The support coefficient stayed negative (−0.17 and −0.19; Model 4 95% CI −0.31 to −0.06; $p = 0.003$). Resource adequacy as categories alone explained 59% of the variance in stability, against 17% for a linear term. The coefficients of

the covariates are given in Table 7. Under the linear term (Model 2), longer farming experience (categories 4 and 5: −0.58, p = 0.011; −0.78, p = 0.004) and education above primary level (−0.56, p = 0.005) were associated with lower stability, but once resource adequacy entered as categories (Model 4) these coefficients shrank to −0.29, −0.34 and −0.25 and none was significant at the 5% level. The only covariate coefficient that differed from zero in Model 4 was the third farm-area category (0.47, p = 0.022). The covariates are reported for completeness and are not interpreted.

Table 6. Regressions of perceived income stability on support, diversification and resource adequacy (standardised outcome; HC3 standard errors in parentheses).

Predictor	Model 1	Model 2	Model 3	Model 4
External institutional support	−0.181 (0.087)*	−0.181 (0.084)*	−0.172 (0.067)**	−0.185 (0.063)**
Diversification practice intensity	−0.317 (0.077)***	−0.206 (0.084)*	0.159 (0.093)	0.112 (0.091)
Resource adequacy, linear (standardised)	0.649 (0.102)***	0.685 (0.105)***	–	–
Resource adequacy: category 2 vs 1	–	–	1.152 (0.304)***	1.161 (0.317)***
Resource adequacy: category 3 vs 1	–	–	2.423 (0.208)***	2.448 (0.199)***
Resource adequacy: category 4 vs 1	–	–	1.414 (0.307)***	1.460 (0.330)***
Covariates	No	Yes	No	Yes
R^2	0.303	0.398	0.619	0.651
Adjusted R^2	0.289	0.352	0.606	0.619
n	156	156	156	156

Note: * p < 0.05, ** p < 0.01, *** p < 0.001 (two-tailed, normal reference). Support and diversification are standardised scales. Category coefficients are differences from the lowest category (n = 18) in standard deviations of stability. Covariates: farming experience (four dummies), farm area (three dummies) and education above primary level; coefficients are in Table 7. Percentile 95% bootstrap intervals (5,000 resamples): Model 2, support −0.35 to −0.02, diversification −0.39 to −0.04, resource 0.51 to 0.87; Model 4, support −0.31 to −0.06, diversification −0.08 to 0.28, categories 2, 3 and 4: 0.63 to 1.81, 2.15 to 2.84 and 0.89 to 2.13. Source: own survey and estimation.

Table 7. Full coefficients of Models 2 and 4 (standardised outcome; HC3 standard errors; p-values in square brackets).

Predictor	Model 2 (linear adequacy)	Model 4 (adequacy as categories)
External institutional support	−0.181 (0.084) [0.031]	−0.185 (0.063) [0.003]
Diversification practice intensity	−0.206 (0.084) [0.015]	0.112 (0.091) [0.219]

Predictor	Model 2 (linear adequacy)	Model 4 (adequacy as categories)
Resource adequacy, linear	0.685 (0.105) [<0.001]	–
Resource adequacy: category 2 vs 1	–	1.161 (0.317) [<0.001]
Resource adequacy: category 3 vs 1	–	2.448 (0.199) [<0.001]
Resource adequacy: category 4 vs 1	–	1.460 (0.330) [<0.001]
Experience category 2 (n = 42)	−0.284 (0.211) [0.178]	−0.196 (0.168) [0.244]
Experience category 3 (n = 46)	−0.238 (0.216) [0.269]	−0.181 (0.170) [0.285]
Experience category 4 (n = 25)	−0.583 (0.229) [0.011]	−0.291 (0.184) [0.113]
Experience category 5 (n = 14)	−0.776 (0.268) [0.004]	−0.335 (0.288) [0.245]
Farm area category 2 (n = 45)	−0.189 (0.179) [0.293]	0.048 (0.133) [0.719]
Farm area category 3 (n = 32)	−0.006 (0.224) [0.977]	0.470 (0.206) [0.022]
Farm area category 4 (n = 9)	−0.480 (0.426) [0.260]	−0.049 (0.290) [0.866]
Education above primary (n = 33)	−0.560 (0.201) [0.005]	−0.254 (0.159) [0.111]
R^2 (adjusted R^2)	0.398 (0.352)	0.651 (0.619)

Note: Reference categories: experience category 1 (n = 29) and farm area category 1 (n = 70). Covariate coefficients are reported for completeness and are not interpreted. Source: own survey and estimation.

Is the Diversification Association Conditional on Resource Adequacy?

A product term suggested that it is (Model 5, Table 8). With the adequacy rating centred and covariates included, the interaction was negative ($\beta = -0.44$, $p < 0.001$) and R^2 was 0.50. The implied diversification slope was positive where resources were rated unavailable (0.89, 95% CI 0.42 to 1.46) or inadequate (0.46, 95% CI 0.12 to 0.85), near zero at 'sufficient' (0.02) and negative at 'adequate' (−0.42, 95% CI −0.60 to −0.27). Both diversification items showed the same sign of interaction when entered separately. Pooled correlations in the lowest two categories (Spearman $\rho = 0.53$, n = 38) and the highest two ($\rho = -0.55$, n = 118) pointed the same way.

This pattern does not survive a flexible resource term. Adding a quadratic adequacy term (Model 6) gave a strongly negative curvature coefficient ($\beta = -0.52$, $p < 0.001$), raised R^2 to 0.62 and reduced the interaction to −0.13 ($p = 0.24$). With adequacy as categories the diversification-by-category terms were jointly weak (Wald $\chi^2(3) = 6.73$, $p = 0.081$; Model 7, $R^2 = 0.67$), and within single categories diversification was unrelated to stability (rank correlations between −0.18 and 0.31, none significant at the 5% level; pooled within-category r = 0.10, Spearman $\rho = 0.02$, $p = 0.81$). Only one single contrast, category 3 against category 1, differed individually (−0.69, $p = 0.019$). The opposite pooled correlations in the lower and upper halves of the scale therefore reflect differences between categories, not relationships within them: the lowest categories pair low diversification with low stability, and the highest category pairs high diversification with lower stability than the middle one. H2 is accordingly not supported once the shape of the resource rating

is allowed for. Dropping the highest category left a negative linear interaction (−0.17, p = 0.031), dropping the lowest did not (−0.21, p = 0.48), which again points to the lowest group.

Table 8 reports Models 5 to 7, and Table 9 collects the within-category and alternative specifications. Regressing stability on diversification and support within each adequacy category gave diversification slopes of −0.06 (p = 0.82), 0.33 (p = 0.32), −0.10 (p = 0.57) and 0.19 (p = 0.20) from the lowest to the highest category. The interaction was also present without covariates (−0.458, p < 0.001; R^2 = 0.426) and with each diversification item entered alone (−0.285 for non-coffee plant types and −0.587 for coffee-waste use), so it did not depend on a single item. A quadratic adequacy term without any interaction nevertheless left the diversification coefficient close to zero, both with covariates (0.016, p = 0.85) and without them (0.024, p = 0.77), and in Model 6 the fitted curve peaked at about 3.05 on the 1–4 rating.

Table 8. Interaction and curvature tests (standardised outcome; HC3 standard errors in parentheses; all models include covariates).

Term	Model 5: linear interaction	Model 6: quadratic and interaction	Model 7: category interactions
Panel A: coefficients			
External institutional support	−0.249 (0.080)**	−0.177 (0.066)**	−0.188 (0.062)**
Diversification practice intensity	0.034 (0.116)	0.064 (0.106)	0.547 (0.281)
Resource adequacy (centred)	0.606 (0.107)***	0.136 (0.135)	–
Resource adequacy, squared	–	−0.520 (0.106)***	–
Diversification × resource adequacy	−0.438 (0.088)***	−0.132 (0.112)	–
Categories 2, 3 and 4 vs 1	–	–	0.94*, 2.01***, 1.22**
Diversification × categories 2, 3 and 4	–	–	−0.11, −0.69*, −0.44
R^2	0.497	0.618	0.671
Adjusted R^2	0.455	0.583	0.633
Panel B: diversification slope implied by Model 5 (95% bootstrap CI)			
RES1 = 1 (n = 18)	0.89 (0.42 to 1.46)		
RES1 = 2 (n = 20)	0.46 (0.12 to 0.85)		
RES1 = 3 (n = 68)	0.02 (−0.20 to 0.25)		
RES1 = 4 (n = 50)	−0.42 (−0.60 to −0.27)		

Note: * p < 0.05, ** p < 0.01, *** p < 0.001. In Model 7 the joint Wald test of the three diversification-by-category terms gives $\chi^2(3) = 6.73$, p = 0.081. Slopes in Panel B are in standard deviations of stability per standard deviation of diversification, evaluated at each observed category with the rating otherwise held at its observed values; intervals are percentiles from 5,000

case resamples. Within single categories diversification was unrelated to stability (Table 9). Source: own survey and estimation.

Table 9. Within-category associations and additional specifications.

Check	Result
Panel A: diversification and stability within categories	
RES1 = 1 (n = 18)	Spearman 0.31 (p = 0.22); regression slope with support held constant −0.06 (p = 0.82)
RES1 = 2 (n = 20)	Spearman 0.19 (p = 0.41); slope 0.33 (p = 0.32)
RES1 = 3 (n = 68)	Spearman −0.18 (p = 0.15); slope −0.10 (p = 0.57)
RES1 = 4 (n = 50)	Spearman 0.12 (p = 0.40); slope 0.19 (p = 0.20)
Lowest two categories pooled (n = 38)	Spearman 0.53 (p = 0.001)
Highest two categories pooled (n = 118)	Spearman −0.55 (p < 0.001)
After removing category means (n = 156)	Pearson 0.10; Spearman 0.02 (p = 0.81)
Panel B: other specifications	
Linear interaction, no covariates	Diversification × adequacy −0.458 (p < 0.001); R^2 0.426
Quadratic adequacy, no interaction, with covariates	Support −0.153 (p = 0.030); diversification 0.016 (p = 0.85); adequacy 0.101; adequacy² −0.584 (p < 0.001); R^2 0.612
Quadratic adequacy, no interaction, no covariates	Support −0.145 (p = 0.053); diversification 0.024 (p = 0.77); adequacy² −0.617 (p < 0.001); R^2 0.571
Quadratic with interaction (Model 6)	Maximum of the quadratic curve at about 3.05 on the 1–4 rating
DIV1 only × adequacy	Interaction −0.285 (p < 0.001)
DIV2 only × adequacy	Interaction −0.587 (p < 0.001)
Highest category dropped (n = 106)	Interaction −0.172 (p = 0.031)
Lowest category dropped (n = 138)	Interaction −0.214 (p = 0.48)
Adequacy categories only (no other predictors)	R^2 0.591; linear adequacy only, R^2 0.174
Influence	Largest Cook's distance in Model 5, 0.088; 13 of 156 cases above 4/n; variance inflation factors in Model 5 up to 2.16

Note: Slopes in Panel A come from regressions of standardised stability on standardised support and diversification within each category (no covariates, because of small n). Source: own survey and estimation.

Institutional Support and Model Diagnostics

Support was negatively associated with stability in every specification (Tables 6 and 8): −0.18 and −0.18 under linear terms, −0.17 and −0.19 under categories, −0.25 with the linear interaction (Model 5), −0.18 with the quadratic term (Model 6; p = 0.008) and −0.19 with category interactions (Model 7). The association is small to moderate, and its 95% bootstrap interval excluded zero in Models 2, 4 and 5. Support correlated positively with diversification (r = 0.43) and resource adequacy (r = 0.33), so the negative sign appears only net of both. H3 is thus supported as an

association without a causal reading. No single household drove the results: the largest Cook's distance in Model 5 was 0.09, with 13 of 156 cases above the 4/n cut-off, and variance inflation factors in the interaction model did not exceed 2.2.

Summary of Hypothesis Tests

Table 10 summarises how the three hypotheses fared. H1 is partly supported: perceived water and soil adequacy was positively associated with perceived income stability, but the relation was not monotone, because stability was lower in the highest category than in the third. H2 is not supported once the shape of the resource rating is allowed for, and H3 is supported only as a negative association whose source the data cannot identify.

Table 10. Summary of the hypothesis tests.

Hypothesis	Evidence (Tables 6 to 9)	Assessment
H1. Higher perceived adequacy of water and soil is associated with higher perceived income stability.	Linear term: $\beta = 0.65$ (Model 1) and 0.69 (Model 2), $p < 0.001$. Categories 2 to 4 sat 1.16, 2.45 and 1.46 SD above category 1 (Model 4), but mean stability fell from 3.02 to 2.40 between the third and fourth categories, and the Spearman correlation (0.14) was much lower than the Pearson correlation (0.42).	Partly supported: positive overall, not monotone
H2. The association between diversification practice intensity and perceived income stability differs by level of resource adequacy.	Linear interaction −0.44 ($p < 0.001$; Model 5), but −0.13 ($p = 0.24$) once a quadratic adequacy term was added (Model 6); category interactions jointly weak (Wald $\chi^2(3) = 6.73$, $p = 0.081$; Model 7); no association within single categories.	Not supported once the shape of the resource rating is allowed for
H3. After diversification and resource adequacy are held constant, external institutional support is associated with perceived income stability.	Negative in every specification (−0.17 to −0.25); the 95% bootstrap interval excluded zero in Models 2, 4 and 5.	Supported as a negative association, without a causal reading

Note: SD, standard deviations of the standardised outcome. Source: own survey and estimation.

Resource Ratings, Functional Form and Diversification

What the data show most clearly is that the resource rating, not the practice count, organises the pattern. Mean stability followed an inverted U across the four observed adequacy categories, and a category-based specification explained about twice as much variance as a linear one. Under the linear term diversification looked harmful (−0.32) and, with an interaction, apparently helpful in poorer and harmful in better-resourced households. Both readings disappeared once the curvature of the rating was allowed for. The diversification coefficient then fell to 0.11 and within categories the association was close to zero. It should not be called a finding about diversification. It shows how easily a practice count can carry a resource signal. For appraisal, a programme can raise the number of visible practices without showing that any household has become more secure under climatic stress. The results argue against activity counts as sufficient indicators of livelihood security. They do not argue against diversification as a development option.

The shape of the resource association needs care. Stability climbed steeply from the lowest to the middle categories and then fell back among households that rated their water and soil as adequate. Households in that highest category were far more diversified and reported more support, so the dip may reflect who falls in that group. The analysis file has no location variable, so it cannot be said whether the dip reflects landscape and exposure, the way the item is worded and scored, a ceiling in how stability is perceived, or a response style, since stability scores in the middle category are tightly clustered (standard deviation 0.39). Through the livelihoods lens the result still points to constraints that shape farmers' choices. Assets and their accessibility decide which diversification pathways exist (Habib et al., 2023; Kishaija et al., 2025), and work in the Eastern Gangetic Plains likewise ties diversification patterns to resource access and institutional conditions (Jackson et al., 2025). The field notes (Table 1) mention water shortages, disturbed flowering and difficulties with drying; they supply local context but do not prove a mechanism. The finding is a reason to measure water access, soil condition and tenure properly. It does not show that infrastructure investment would raise income stability by any particular amount.

Constrained Diversification

Distress diversification would be one way to explain a negative practice coefficient, but the evidence for it is weak. The negative coefficient appeared only under a linear resource term, weakened after household adjustment and was absent when resources were treated as categories. The positive slope at low adequacy in the interaction model is equally fragile, and a positive slope there would not by itself show that households diversify to cope. Constrained choice, labour competition and differences in farm scale remain possible, and the survey recorded neither motive nor timing. Calling the pattern a demonstrated distress response, or a demonstrated protective effect, would go beyond the evidence.

Institutional Support and Programme Targeting

The negative association between support and stability was the most stable coefficient in the analysis. It does not mean that assistance harms households. Contact with institutions can follow farmers' existing circumstances, and the distribution of programme benefits varies with household position and value-chain ties (Trejo-Pech et al., 2023; Vicol et al., 2018). Support was reported as largely absent here, with item means below 1.7, and it correlated positively with practices and resources, so it appears to reach better-placed households yet is linked to lower perceived stability once those are held constant. The construct combines public assistance, farmer cooperation and marketing ties, so these data identify no single programme or group of beneficiaries. They justify looking into targeting, delivery and perceived benefit. They do not show that either mechanism operates.

Contribution to the Literature

The results qualify two common readings of diversification in coffee livelihoods. Studies of diversified farming systems report improved soil function, higher profit and lower risk (Assefa et al., 2021; Harkness et al., 2021; Kumari et al., 2024; Sun et al., 2025), but they use measured agronomic, economic or environmental outcomes. The outcome here is the perceived continuity of household income under extreme weather, and once the resource rating was allowed its own

shape the practice coefficient could not be distinguished from zero (0.11, 95% CI −0.08 to 0.28). The result is compatible with the livelihoods literature that treats measured diversification as a sign of either opportunity or necessity (Ellis, 2000; Makate et al., 2023; Rubiyanto & Hirota, 2021), because a count of practices cannot separate the two without information on the resources behind it. It also fits the finding from Chiapas that what a coffee farm diversifies into matters more than how much it diversifies (Anderzén et al., 2020), although the two-item practice scale used here cannot describe the composition of diversification.

The methodological point is narrower. A single, non-monotone resource rating can distort the coefficients of practices that correlate with it, which is why the functional form of such ratings should be inspected before they are used as controls or combined with practices in composite indicators, as many adaptation indices do. The point is a caution about specification and may be relevant beyond this case, but it rests on one sample, one item and exploratory models, and it needs replication with objective resource measures.

Practical and Policy Implications

The implications concern how programmes are designed and judged, not which intervention to rank first. Evaluations should keep what households do (extra crops, recycling of residues) apart from the water and soil conditions and institutional ties that make those activities feasible, and should check whether a rating of resources is related to outcomes in a straight line before using it as a control. Extension staff could check whether a new practice fits within seasonal labour, whether farmers have enough water and workable soils, and whether extra crops have buyers who pay. Monitoring should add indicators of actual income continuity and of recovery after shocks to the counts of practices or beneficiaries (Bracken et al., 2023; Poncet et al., 2024). The data cannot show whether support for resources should come before diversification, whether a combined package would do better, or which households deserve priority. Those questions need longitudinal or prospective evaluation that separates the resilience of coffee supply from that of farming households (Grabs et al., 2026).

Research Limitations

The data are cross-sectional and based on perception, the sample is non-probabilistic, and the associations are neither external validation nor an independent replication. The category-based and interaction specifications were chosen after inspecting the data, so p-values are descriptive, and the category groups are small (18 and 20 households at the low end). RES1 asks about water and soil in one item, so the two dimensions and the item's reliability cannot be separated, its coding could not be checked against the printed questionnaire, and its non-monotone relation to stability may reflect scoring, response style or unmeasured location effects. The diversification scale has two items and leans towards residue recycling. Perceived income stability is neither an observed income series nor an independently validated measure of resilience, and a cross-sectional design cannot establish temporal order or recovery after a shock. Alternative explanations include common-method effects (Podsakoff et al., 2024), reverse causality, distress diversification and targeted support. The covariates cover recorded farming experience, education and farm-area categories; age and survey area were recorded in the survey programme but are missing from the

linked analysis file. The same survey programme supports other analyses with different outcomes, so findings here should not be treated as independent of them. Finally, support was reported as nearly absent, which limits what can be said about its quality. Later studies should pair repeated income records with objective resource measures and dated records of adoption and participation, and validate the scales independently (Podsakoff et al., 2024; Vaithilingam et al., 2024).

CONCLUSION

Across the 156 upland coffee households surveyed in East Java, the stability of income under extreme weather, as perceived by farmers, followed an inverted U across the four observed categories of perceived water and soil adequacy (means 1.31, 2.20, 3.02 and 2.40), and treating adequacy as categories raised explained variance from 0.30 to 0.62. The diversification coefficient was −0.32 with a linear adequacy term, −0.21 with covariates and 0.11 (not significant) with categories, so the negative sign should not be read as evidence that diversification lowers stability. An interaction suggesting a positive diversification slope at low and a negative slope at high adequacy disappeared when a quadratic adequacy term was added, and within single categories diversification was unrelated to stability.

External institutional support, reported as nearly absent, was negatively associated with stability in every specification (−0.17 to −0.25), net of practices and resources; the data do not show whether this reflects targeting or delivery. Counts of practices alone should not be taken as evidence of livelihood security or resilience, and resource ratings should be checked for non-linearity before they are used as controls.

The study neither measures resilience as a whole nor shows that a programme works or which intervention should come first. Longitudinal outcomes, objective resource measures and stronger household and location controls are required.

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