Journal of Economics, Entrepreneurship, Management Business and Accounting, 2026, 4(5), 2527-2539.
https://doi.org/10.61255/jeemba.v4i5.2372

Economic and environmental assessment of chili farming in Gunung Kerinci, Indonesia

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ABSTRACT

Purpose – This study describes farm-budget outcomes and separately reported environmental indicators associated with chili cultivation in Gunung Kerinci District, Indonesia.
Design/methodology/approach – A descriptive quantitative assessment used 15 purposively selected 0.5-ha farm records for one cropping season and six independent site-level environmental records. Production costs and revenue were reconciled arithmetically, and the environmental values were summarized without imputing missing inventories or linking sites to particular farms.
Findings/Results – The mean recorded farm cost was IDR 14,385,000 and gross revenue was IDR 23,040,000, yielding a mean accounting surplus of IDR 8,655,000 and a mean revenue-to-recorded-cost ratio of approximately 1.60. The six site records reported mean carbon and water indicators of 2.65 t CO_2-eq/ha and 3,300 m^3/ha, respectively; their measurement basis was not sufficiently documented to confirm a complete LCA.
Originality/Value – The analysis juxtaposes local farm budgets and environmental indicators while distinguishing supported descriptive conclusions from untested causal trade-offs. Its principal implication is the need for linked farm-level economic and environmental monitoring.

ARTICLE INFO

Keywords:
Chili farming; Farm-budget accounting; Revenue-to-cost ratio; Environmental indicators; Sustainable agriculture.

Article Information:
Received: 08/07/2026
Revise: 20/08/2026
Accepted: 26/09/2026

ISSN:
2985-3168 (Online)
2985-3222 (Print)

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1. Introduction

Agricultural intensification poses a practical dilemma for horticultural regions: greater marketable output can support farm income, but the same production decisions may increase pressure on soil, water, and surrounding ecosystems. Evidence from the global food system shows that this tension cannot be evaluated by yield alone, because environmental burdens vary across crops, places, and management practices (Beyer et al., 2022; Jwaideh & Dalin, 2025; Abdo et al., 2025). Nitrogen fertilization is especially relevant because its economic contribution must be considered alongside upstream and field-level greenhouse-gas emissions (Gao & Serrenho, 2023). Research on small farms also indicates that farm size does not provide a reliable shortcut for inferring either profitability or environmental efficiency (Ricciardi et al., 2021). A local assessment therefore needs to consider the financial and ecological dimensions together, while keeping their distinct measurement bases visible.

Chili cultivation offers a concrete setting for this problem in Gunung Kerinci District, Kerinci Regency, Jambi Province. As described in the source study, the locality is an agricultural production area in which farmers use purchased inputs, including fertilizer, pesticides, seedlings, and labor, to maintain seasonal chili production (BPS, 2023). These expenditures are directly reflected in farm budgets, whereas potential impacts on water, soil, and biodiversity do not necessarily appear as private production costs. Research on Indonesian vegetable production illustrates why this distinction matters: an LCA of farms in West Java identified crop yield and fertilizer management as important determinants of environmental impact intensity (Kashyap et al., 2023), while research on bell peppers and tomatoes shows the significance of crop-specific LCA boundaries (Srinivasan & Yadav, 2024; Naseer et al., 2022). However, estimates from a different province cannot be substituted for environmental measurements in Kerinci. Site-specific economic accounts and ecological observations are therefore needed.

The economic assessment of intensive cultivation must distinguish gross revenue from what remains after paying for recorded inputs. Input-use research stresses that agricultural performance depends on input combinations rather than on one expenditure item in isolation (Suh & Moss, 2021). Recent work has likewise shown that a seemingly productive fertilizer strategy may not coincide with the rate that minimizes external environmental costs (Baum et al., 2025). Evidence from vegetable systems indicates that better-directed nitrogen management may provide environmental and economic benefits, although such outcomes depend on crop, baseline practice, and local conditions (Tian et al., 2025). Consequently, a positive revenue-to-cost ratio can identify short-run accounting profitability but cannot by itself establish long-run sustainability.

Environmental analysis introduces a parallel measurement challenge. Agricultural footprints involve different dimensions, including greenhouse-gas emissions, water consumption, and effects linked to nutrients or crop protection products (Tang et al., 2022; Schulte-Uebbing et al., 2022). Water-footprint research has shown that irrigation pressures depend on hydrological conditions and management design rather than on a universal volume that is efficient in every setting (Giordano et al., 2023; Ketchum et al., 2023). Moreover, recent evidence links pesticides to soil-fauna responses and the functioning of beneficial soil organisms (Beaumelle et al., 2023; Köninger et al., 2026). These findings justify examining several indicators together, but they also require care when interpreting site-level measurements as environmental impacts.

One strand of current research quantifies economic and ecological performance within the same production system. For example, Zhang et al. (2024) adopt a life-cycle perspective in evaluating environmental–economic productivity in vegetable production, while Touch et al. (2025) examine differences among agricultural input strategies and their economic and environmental implications. Studies of organic vegetable production further demonstrate that environmental burdens may shift among cultivation, propagation, and postharvest stages rather than disappear under a single label such as organic (Jensen et al., 2024; Krause et al., 2024). Evidence from diversified landscapes similarly documents input-specific changes in resource use, making broad claims that diversification reduces every environmental burden inappropriate (Wang et al., 2024). This literature favors disaggregated measurements over an undifferentiated sustainability score.

A second strand examines the mechanisms through which intensification changes ecosystem function. Ecological analyses associate intensive agricultural land use with changes in insect biodiversity (Outhwaite et al., 2022), while systems modeling identifies conditions under which biodiversity loss can feed back into future agricultural production (Burian et al., 2024). More recent evidence suggests that diversification can improve ecosystem services and financial outcomes over time, but these gains may depend on the duration and form of implementation (Raveloaritiana & Wanger, 2026). Such studies provide mechanisms and plausible management options, not direct evidence that the environmental indicators observed in Gunung Kerinci have already reduced chili yields or income. A study of the present locality must therefore separate environmental concerns from causal claims that its own dataset cannot test.

Against this background, the study aims to describe farm-level revenue, recorded production expenditure, and environmental indicators reported for chili-growing locations in Gunung Kerinci. The economic component summarizes 15 purposively selected farm records; the environmental component summarizes six separately reported locations. The two datasets were presented side by side to identify decision-relevant information, not to test a causal relationship between management practices and environmental outcomes. This narrower objective responds to the need for transparent, locally grounded accounting without implying that the available observations establish long-term sustainability. The contribution lies in identifying the economic position of the sampled farms and the information gaps that must be addressed before an integrated valuation is possible.

2. Literature Review and Analytical Framework

2.1. Farm accounting returns and input allocation

Farm-budget accounting uses the amount received from sales and the expenses recorded by each producer to describe a short-run financial margin. A ratio above one indicates revenue greater than the stated costs, but this is not evidence of positive net social benefits or long-term economic efficiency if other costs are excluded (Boardman, 2014; Mishan & Quah, 2007). Research on agricultural input-output linkages cautions against inferring optimal input allocation from expenditure categories alone (Suh & Moss, 2021). Recent comparisons of nitrogen fertilizer use show that the rate maximizing economic return may differ from the rate associated with reduced environmental losses (Baum et al., 2025; Tian et al., 2025). These distinctions are essential for the Gunung Kerinci accounts, which record expenses but not physical input quantities, harvest volumes, or all possible fixed costs.

2.2. Agricultural environmental indicators

Life Cycle Assessment (LCA) typically identifies a functional unit and system boundary and then characterizes emissions and resource use across defined processes (Kashyap et al., 2023; Jensen et al., 2024). Such choices matter when comparing impact estimates across studies, particularly where one result is reported per hectare per season and another per tonne of output or per year. Fertilizer manufacture and application contribute to agricultural emissions (Gao & Serrenho, 2023), while pesticide footprints and their spatial mapping represent a separate set of ecological pressures (Tang et al., 2022; Douglas et al., 2022). Evidence from soil ecology highlights the distinction between observing a proxy indicator and quantifying biological change through repeated measurements (Beaumelle et al., 2023; Teng et al., 2024). The present analysis consequently treats its six environmental measurements as study-reported site indicators rather than a complete comparable product LCA.

2.3. An integrated decision perspective

Economic and environmental indicators may point in different directions, but a trade-off requires comparable units and linked observations before it can be quantified. Studies that combine life-cycle methods with economic assessments show the value of stating input boundaries and clearly specifying the scale of analysis (Zhang et al., 2024; Touch et al., 2025). Management changes can produce different outcomes depending on the crop and baseline context, as illustrated by diversification experiments and synthesis research (Kasten et al., 2024; Raveloaritiana & Wanger, 2026). For Gunung Kerinci, the available 15-farm accounts and six environmental-site measurements support a juxtaposition of indicators, not estimation of their farm-by-farm covariance. The analytical framework therefore separates descriptive economic performance, the reported econometric specification, and environmental measurements before considering their practical implications.

3. Methodology

3.1. Research design and study area

The investigation used a descriptive quantitative design to examine farm accounting records and reported environmental indicators from chili cultivation in Gunung Kerinci District, Kerinci Regency, Jambi Province, Indonesia. The available material contains 15 farm-level financial records and six separately tabulated environmental-site observations. The analysis proceeded through arithmetic reconciliation of farm input costs, calculation of descriptive farm-budget outcomes, and summarization of the six environmental indicator series. The data collection date and observation interval for the environmental measurements are not specified in the supplied study report; accordingly, the analysis does not assign dates or infer seasonal trends. These datasets were considered separate units of observation, and no causal, spatial interpolation, or farm-level trade-off model was estimated.

3.2. Sampling and observed locations

Purposive sampling included 15 farmers who had cultivated chili for at least three years, used intensive input-management practices, lived in the study area, and cultivated at least 0.5 ha. The respondent list recorded 15 plots of 0.5 ha each across Siulak Deras, Sungai Batu Gantih, Siulak Deras Mudik, Siulak Tenang, Tanjung Genting Mudik, and Sungai Betung Hilir. Thirteen were listed as large red chili plots and two as bird's-eye chili plots. Because the economic records were not disaggregated by cultivar, the reported financial outcomes describe

this pooled sample and cannot be interpreted as estimates for red chili alone. Six environmental measurements were listed independently without respondent-to-site identifiers or sufficient methods to infer direct correspondence with the farm accounts.

Table 1. Distribution of chili-farm respondents by study location

Village / locality	Large red chili	Bird's-eye chili	Total farms
Siulak Deras	2	1	3
Sungai Batu Gantih	1	1	2
Siulak Deras Mudik	3	0	3
Siulak Tenang	2	0	2
Tanjung Genting Mudik	3	0	3
Sungai Betung Hilir	2	0	2
Total	13	2	15

3.3. Farm-budget accounting and arithmetic reconciliation

For one reported cropping season, each farm record comprised expenditures on fertilizer, pesticides, seedlings, and labor, together with gross sales revenue. We first summed these four expenditure components to obtain the recorded cost for each respondent. Accounting surplus was calculated as revenue minus these stated costs, and a revenue-to-recorded-cost ratio was calculated separately for each farm. The sample summaries report arithmetic means of the 15 farm-level values; the mean individual ratio is distinguished from the ratio of summed revenue to summed recorded expenses. When a cost total in the source table did not equal its printed components, the component sum was used; no underlying component or revenue entry was changed. These are farm-budget indicators rather than a social cost–benefit assessment, because land rent, depreciation, opportunity costs, and environmental externalities were not documented.

$$\text{Accounting surplus}_i = \text{Gross revenue}_i - (\text{Fertilizer}_i + \text{Pesticides}_i + \text{Seedlings}_i + \text{Labor}_i) \quad (1)$$

$$\text{Revenue-to-recorded-cost ratio}_i = \text{Gross revenue}_i / \text{Sum of four recorded costs}_i \quad (2)$$

3.4. Environmental measurements and analytical integration

The six environmental-site records (R1–R6) included figures described in the original study as carbon footprint, water footprint, fertilizer-related N_2O emissions, soil degradation, nitrate concentration, and biodiversity loss. Arithmetic means and observed ranges were calculated from the six listed entries, but original measurement protocols, calculation factors, environmental baselines, and full life-cycle system boundaries were not provided. Accordingly, these results are referred to as reported environmental indicators, not independently validated life-cycle impact estimates or proof that a regulatory threshold has been exceeded. Fifteen farm-location coordinates were also supplied in the respondent list and were plotted only to illustrate the distribution of recorded farm plots. The environmental-site indicators were synthesized alongside farm budget outcomes, without assuming that the coordinate plot identified their six separate measurement sites.

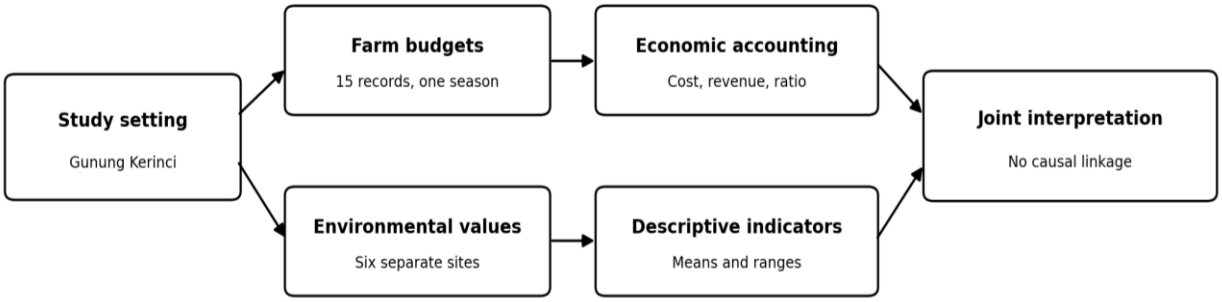


Figure 1. Analytical workflow separating 15 farm accounts from six environmental records. Source: Adapted from the information presented in the original manuscript.

4. Results and Discussion

4.1. Farm-level economic outcomes

Table 2 reproduces the printed individual expenditures and gross revenues for the 15 respondents. Respondent-level total costs, accounting surpluses, and revenue-to-recorded-cost ratios were recalculated using the reported components; the source totals were inconsistent for respondents D, G, H, and M. The expenses presented here cover the four stated input categories and do not establish full economic costs. All monetary amounts relate to one recorded cultivation season for a 0.5-ha plot. As two sampled plots were classified as bird's-eye chili, the economic aggregate represents the combined sample rather than a single cultivar.

Table 2. Farm-budget items and recalculated accounting outcomes per cultivation season (IDR per 0.5-ha plot)

	Fertilizer	**Pesticide**	**Seedlings**	**Labor**	**Total cost**	**Revenue**	Surplus	R/C
A	2,200,000	1,520,000	1,600,000	8,000,000	13,320,000	20,000,000	6,680,000	1.50
B	1,840,000	1,440,000	2,400,000	9,600,000	15,280,000	24,000,000	8,720,000	1.57
C	2,560,000	1,440,000	2,000,000	8,400,000	14,400,000	22,000,000	7,600,000	1.53
D	1,992,000	1,560,000	2,240,000	9,200,000	14,992,000	24,800,000	9,808,000	1.65
E	2,368,000	1,560,000	1,760,000	8,000,000	13,688,000	22,400,000	8,712,000	1.64
F	2,250,000	1,470,000	1,800,000	8,200,000	13,720,000	21,600,000	7,880,000	1.57
G	2,365,000	1,490,000	2,100,000	8,600,000	14,555,000	23,000,000	8,445,000	1.58
H	2,070,000	1,420,000	1,700,000	7,800,000	12,990,000	20,800,000	7,810,000	1.60
I	2,150,000	1,370,000	1,900,000	8,100,000	13,520,000	21,900,000	8,380,000	1.62
J	2,435,000	1,600,000	2,300,000	8,800,000	15,135,000	24,500,000	9,365,000	1.62
K	2,280,000	1,550,000	2,000,000	8,400,000	14,230,000	23,600,000	9,370,000	1.66
L	2,190,000	1,430,000	1,800,000	8,200,000	13,620,000	21,500,000	7,880,000	1.58
M	2,515,000	1,490,000	2,200,000	8,700,000	14,905,000	24,000,000	9,095,000	1.61
N	2,850,000	1,750,000	2,500,000	9,000,000	16,100,000	26,500,000	10,400,000	1.65
O	2,550,000	1,570,000	2,300,000	8,900,000	15,320,000	25,000,000	9,680,000	1.63
Mean	**2,307,667**	**1,510,667**	**2,040,000**	**8,526,667**	**14,385,000**	**23,040,000**	**8,655,000**	**1.60**

Mean recorded expenditure was IDR 14,385,000 per plot and mean gross revenue was IDR 23,040,000, leaving a mean accounting surplus of IDR 8,655,000. The mean respondent-level revenue-to-recorded-cost ratio was approximately 1.60, and all 15 farm records show gross revenue above the four stated expenditure categories. This pattern indicates positive margins within the recorded farm budgets, not independently confirmed total economic profits. The different crop categories, the purposive sample, and the absence of fixed and nonmarket costs limit comparisons beyond the observed farms.

4.2. Reported environmental indicators

The original respondent list supplies geographic coordinates for the 15 farm plots, displayed in Figure 2 as a coordinate plot without a cartographic basemap. The environmental data, separately presented for six sites labeled R1–R6, do not provide an explicit mapping from those sites to individual farmers or to these farm coordinates. Accordingly, the figure shows farm locations only, and the environmental table remains an independent six-record descriptive summary. The available records do not support an interpolated contamination map, spatial exposure estimates, or allocation of environmental indicators to particular farm budgets.

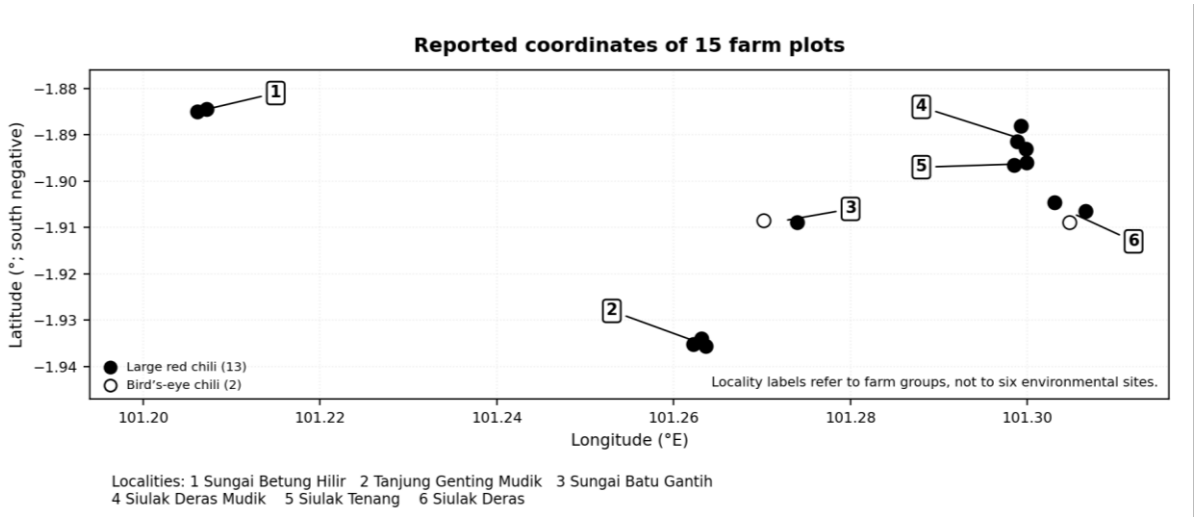


Figure 2. Coordinates of 15 chili-farm plots across six localities. The plotted farm sites are distinct from unlinked environmental records R1–R6. Source: Respondent coordinates in the original manuscript.

Table 3. Reported environmental indicators for six unlinked observation sites

Indicator	R1	R2	R3	R4	R5	R6	Mean
Carbon footprint (t CO_2-eq/ha)	2.4	2.6	2.5	2.8	2.7	2.9	2.65
Water footprint (m^3/ha)	3,200	3,300	3,100	3,400	3,300	3,500	3,300
Reported fertilizer N_2O (kg/ha)	1.0	1.3	1.2	1.4	1.3	1.5	1.28
Reported soil degradation (%)	14	16	13	17	15	18	15.50
Nitrate concentration (mg/L)	28	30	29	32	31	33	30.50
Reported biodiversity loss (%)	18	19	20	21	19	22	19.83

The site-level records list carbon-footprint values of 2.4–2.9 t CO_2-eq/ha (mean 2.65) and water-footprint values of 3,100–3,500 m^3/ha (mean 3,300). Reported fertilizer-related N_2O entries yield a sum of 7.7 and a mean of 1.28 kg/ha, rather than the original printed total and mean. The mean listed values for soil degradation, nitrate concentration, and biodiversity loss were 15.50%, 30.50 mg/L, and 19.83%, respectively. These numbers reproduce the available site summaries, but missing baseline definitions and measurement methods prevent interpretation of the percentage indicators as verified changes over time. The nitrate entries cannot be compared to a specific drinking-water criterion without knowing which nitrate species, unit convention, and water source were measured.

4.3. Discussion

All 15 observed farms recorded positive accounting surpluses over the four stated spending categories, but this is not equivalent to a comprehensive profitability or social welfare assessment. Because the calculations omit any unreported rent, depreciation, interest, family labor opportunity cost, and nonmarket environmental damage, the ratio of approximately 1.60 is best treated as a short-run revenue-to-recorded-cost indicator. Classical cost–benefit analysis distinguishes accounting transfers and private expenses from broader societal benefits and costs (Boardman, 2014; Mishan & Quah, 2007). Empirical studies show that agricultural output, farmer welfare, and environmental performance can respond differently to the same production system (Ricciardi et al., 2021; Jwaideh & Dalin, 2025). The practical value of the Gunung Kerinci accounts is thus an explicit and reproducible budget baseline. Whether alternative input strategies would preserve margins after all relevant costs are included has not been tested in this dataset.

Labor represented the largest documented production expense, averaging IDR 8,526,667 or approximately 59% of the four recorded costs. Fertilizer and pesticide expenditures were comparatively smaller, and their recorded amounts are monetary purchases rather than direct measures of application intensity. A decision to reduce any one expense cannot be assumed to raise net returns because crop yield, input substitution, and hired-labor requirements may change simultaneously. The distinction matters when interpreting studies of nutrient optimization, which evaluate both the agronomic response to physical fertilizer inputs and the prices paid for those inputs (Baum et al., 2025; Gong et al., 2025; Tian et al., 2025). Farm-level records of input quantities, product grades, sale prices, and labor days would be needed to evaluate marginal returns in this setting. In their absence, the cost-share results identify where farms spent money but do not identify the economically optimal input combination.

The mean carbon-footprint entry signals the relevance of greenhouse-gas reporting to the farming system, but it cannot be treated as a verified product life-cycle footprint. The available evidence lacks a defined functional unit, time horizon, activity inventory, emission factors, and stated boundaries for fertilizer production, field operations, or transport. Studies of vegetable cultivation in West Java and Denmark show how such boundary choices influence the interpretation of environmental impacts (Kashyap et al., 2023; Jensen et al., 2024). Nitrogen fertilizer assessments also distinguish upstream manufacturing emissions from direct and indirect field emissions (Gao & Serrenho, 2023; Abdo et al., 2025). It would therefore be misleading to present a numerical comparison with the cited ISO carbon-footprint standard as proof of breaching a universal limit. A reproducible inventory would be necessary before comparing the Gunung Kerinci figure with impact estimates from other production systems.

The water-footprint values provide an additional description of resource demand, yet their interpretation depends on how water withdrawals, rainwater, and production output were measured. An area-based figure alone does not establish inefficient irrigation or local water scarcity, particularly in the absence of rainfall, crop yield, irrigation source, and growing-period information. Irrigation and watershed studies have documented substantial variation in water outcomes with management and location (Giordano et al., 2023; Ketchum et al., 2023; Li et al., 2023). Experimental evidence from other crops suggests that targeted water and nutrient management may improve use efficiency, but those results cannot be directly transferred to the chili farms without local comparison (Gupta et al., 2023). Future plot-level records should distinguish water sources and report water use per unit of saleable harvest as

well as per unit of cultivated area. This would allow resource efficiency to be assessed on more defensible grounds.

The reported soil, nitrate, and biodiversity numbers describe dimensions of environmental concern but do not identify environmental change caused by the sampled farms. The entries labeled soil degradation and biodiversity loss are expressed as percentages, although no reference state, observation period, or index formula was supplied; they should therefore not be used to quantify deterioration attributable to chili intensification. Studies of soil fauna and pesticide residues provide a plausible reason to investigate ecological outcomes of pest management (Beaumelle et al., 2023; Köninger et al., 2026). Broader evidence documents changes in insect diversity associated with land use and climate, while emphasizing substantial contextual differences (Outhwaite et al., 2022). The water-nitrate figures also require clarification of chemical expression and sampling context before any comparison with drinking-water criteria can be made. These limitations call for paired baseline and follow-up observations rather than stronger causal wording.

The economic observations describe 15 farm budgets, whereas the environmental observations describe six unlinked sites. They cannot establish whether a particular farm received higher income at the expense of greater ecological burden, nor can the descriptive differences be interpreted as a statistical relationship. Integrated environmental-economic research makes clear that linked units, matching periods, and equivalent production boundaries are prerequisites for testing a trade-off (Zhang et al., 2024; Touch et al., 2025). Broader modeling studies offer mechanisms through which biodiversity loss may feed back into output (Burian et al., 2024), but they do not demonstrate that this mechanism occurred in the surveyed plots. The more modest contribution of this article is to place documented private farm budgets next to reported local environmental values and identify where more coordinated monitoring is needed. Its findings should therefore inform research design and provisional management priorities, not a claimed optimum between economic and environmental outcomes.

Policy options should be evaluated as hypotheses rather than as interventions already validated for Gunung Kerinci. Global and regional studies suggest that crop diversification, landscape features, and modified cultivation practices can influence pest pressure, agricultural returns, and biodiversity (Zhang et al., 2025; Chandel et al., 2025; Klinnert et al., 2024; Kasten et al., 2024; Raveloaritiana & Wanger, 2026). Their suitability for the present study area remains uncertain because the current accounts do not record treatment protocols or controlled outcomes. A useful next step is to record physical quantities of fertilizers and pesticides, harvested output, sale prices, actual water use, and repeated soil or biodiversity indicators on the same plots. Farmers should also be included when identifying feasible alternatives, consistent with participatory approaches to environmental land management (Hurley et al., 2022). Linked longitudinal data would enable stronger economic and environmental comparisons than the present descriptive study permits.

5. Conclusion and Suggestion

The 15 reported chili-farm budgets showed gross revenue above the four recorded expenditure categories in one cultivation season. Arithmetic reconciliation of component-level costs produced a mean recorded cost of IDR 14,385,000 and mean gross revenue of IDR 23,040,000, corresponding to a mean accounting surplus of IDR 8,655,000 per 0.5-ha plot. The mean farm-level revenue-to-recorded-cost ratio was approximately 1.60. Independently, the environmental component provided six sets of reported values for carbon and water

footprints, N_2O, soil status, water nitrate, and biodiversity indicators. These findings are appropriately interpreted as local descriptive observations; they neither validate a complete life-cycle assessment nor establish that financial returns caused specific environmental impacts.

Extension services and farm managers could prioritize standardized recording of production expenses, marketable yield, input quantities, irrigation, and repeated environmental observations. The results do not warrant recommending a particular fertilizer, pest-control, or irrigation technique as demonstrably superior in Gunung Kerinci. Instead, paired field comparisons could provide the evidence needed to assess economic viability and environmental performance within the same farms and seasonal boundary.

6. Limitations and Future Research

The sample comprised 15 purposively selected farm budgets, including two plots classified as bird's-eye chili, and six environmental observations that were not linked to individual farms. Only the reported four cost categories were available, so the accounting surplus excludes unspecified fixed, opportunity, and environmental costs. The financial sample was not disaggregated by cultivar, and neither plot-level physical yield nor a consistent observation date was provided. The Cobb–Douglas results in the original report were omitted from inferential analysis because their t statistics and p values were internally inconsistent and the source records were insufficient for reproducible estimation. The environmental data lacked documented inventory methods, baselines, and measurement protocols for a full life-cycle assessment. These limitations preclude representative regional profitability estimates, quantified ecological change, or causal claims about economic–environmental trade-offs.

Future research should observe the same plots over multiple cultivation seasons and record crop type, harvested quantity, market prices, physical inputs, labor days, irrigation, and all material cost categories. Explicit system boundaries, impact factors, and baseline procedures would strengthen environmental accounting, and linked observations could support estimation of how input choices relate to returns and ecological outcomes. A reliable Cobb–Douglas or other production model would require original farm-level yield and input data, a defined estimation specification, and complete diagnostics. Comparison of well-defined management alternatives would then allow stronger tests of both financial and environmental effects.

Declaration of AI and AI-assisted technologies in the writing process

During manuscript preparation, an AI-assisted writing tool was used to improve English-language presentation, reorganize sections according to the JEEMBA template, and check arithmetic consistency. The author remains responsible for reviewing the manuscript and ensuring the accuracy of all data, citations, interpretations, and disclosures.

References

Abdo, A. I., Sun, D., Shi, Z., Abdel-Fattah, M. K., Zhang, J., & Kuzyakov, Y. (2025). Conventional agriculture increases global warming while decreasing system sustainability. *Nature Climate Change*, *15*, 110–117. https://doi.org/10.1038/s41558-024-02170-4

Baum, M. E., Sawyer, J. E., Nafziger, E. D., Castellano, M. J., McDaniel, M. D., Licht, M. A., Hayes, D. J., Helmers, M. J., & Archontoulis, S. V. (2025). The optimum nitrogen fertilizer

rate for maize in the US Midwest is increasing. *Nature Communications*, *16*, 404. https://doi.org/10.1038/s41467-024-55314-7

Beaumelle, L., Tison, L., Eisenhauer, N., Hines, J., Malladi, S., Pelosi, C., Thouvenot, L., & Phillips, H. R. P. (2023). Pesticide effects on soil fauna communities—A meta-analysis. *Journal of Applied Ecology*, *60(7)*, 1239–1253. https://doi.org/10.1111/1365-2664.14437

Beyer, R. M., Hua, F., Martin, P. A., Manica, A., & Rademacher, T. (2022). Relocating croplands could drastically reduce the environmental impacts of global food production. *Communications Earth & Environment*, *3*, 49. https://doi.org/10.1038/s43247-022-00360-6

Boardman, A. E. (2014). *Cost-benefit analysis: Concepts and practice.* Pearson Education Limited |.

BPS. (2023). *Kecamatan Gunung Kerinci dalam angka.* Badan Pusat Statistik |.

Burian, A., Kremen, C., Wu, J. S.-T., Beckmann, M., Bulling, M., Garibaldi, L. A., Krisztin, T., Mehrabi, Z., Ramankutty, N., & Seppelt, R. (2024). Biodiversity–production feedback effects lead to intensification traps in agricultural landscapes. *Nature Ecology & Evolution*, *8*, 752–760. https://doi.org/10.1038/s41559-024-02349-0

Chandel, N., Wani, S. A., Lone, M. A., Alqasem, O. A., Rather, A. A., Mir, S. A., Qayoom, D., Nagy, M., Mekiso, G. T., & Balogun, O. S. (2025). Strategic vegetable crop distribution in Himachal Pradesh for sustainable economic and environmental outcomes. *Scientific Reports*, *15*, 19437. https://doi.org/10.1038/s41598-025-04212-z

Douglas, M. R., Baisley, P., Soba, S., Kammerer, M., Lonsdorf, E. V., & Grozinger, C. M. (2022). Putting pesticides on the map for pollinator research and conservation. *Scientific Data*, *9*, 571. https://doi.org/10.1038/s41597-022-01584-z

Gao, Y., & Serrenho, A. C. (2023). Greenhouse gas emissions from nitrogen fertilizers could be reduced by up to one-fifth of current levels by 2050 with combined interventions. *Nature Food*, *4*, 170–178. https://doi.org/10.1038/s43016-023-00698-w

Giordano, V., Tuninetti, M., & Laio, F. (2023). Efficient agricultural practices in Africa reduce crop water footprint despite climate change, but rely on blue water resources. *Communications Earth & Environment*, *4*, 475. https://doi.org/10.1038/s43247-023-01125-5

Gong, H., Yin, Y., Chen, Z., Zhang, Q., Tian, X., Wang, Z., Wang, Y., & Cui, Z. (2025). A dynamic optimization of soil phosphorus status approach could reduce phosphorus fertilizer use by half in China. *Nature Communications*, *16*, 976. https://doi.org/10.1038/s41467-025-56178-1

Gupta, N., Singh, Y., Jat, H. S., Singh, L. K., Choudhary, K. M., Sidhu, H. S., Gathala, M. K., & Jat, M. L. (2023). Precise irrigation water and nitrogen management improve water and nitrogen use efficiencies under conservation agriculture in the maize-wheat systems. *Scientific Reports*, *13*, 12060. https://doi.org/10.1038/s41598-023-38953-6

Hurley, P., Lyon, J., Hall, J., Little, R., Tsouvalis, J., White, V., & Rose, D. C. (2022). Co-designing the environmental land management scheme in England: The why, who and how of engaging harder to reach stakeholders. *People and Nature*, *4(3)*, | 10.1002/pan3.10313. https://doi.org/

Jensen, A., Mogensen, L., van der Werf, H. M. G., Xie, Y., Knudsen, M. T., & Kristensen, H. L. (2024). Environmental impacts and potential mitigation options for organic open-field vegetable production in Denmark assessed through life cycle assessment. *Sustainable Production and Consumption*, *46*, 132–145. https://doi.org/10.1016/j.spc.2024.02.008

Jwaideh, M. A. A., & Dalin, C. (2025). The multi-dimensional environmental impact of global crop commodities. *Nature Sustainability*, *8*, 396–410. https://doi.org/10.1038/s41893-025-01528-6

Kashyap, D., de Vries, M., Pronk, A., & Adiyoga, W. (2023). Environmental impact assessment of vegetable production in West Java, Indonesia. *Science of the Total Environment*, *864*, 160999. https://doi.org/10.1016/j.scitotenv.2022.160999

Kasten, M. K., Witte, F., Sponagel, C., Bahrs, E., Köhler, T., Morinière, J., & Grass, I. (2024). Mineral-ecological cropping systems mitigate biodiversity-productivity trade-offs of the organic vs. conventional farming dichotomy. *npj Sustainable Agriculture*, *2*, 29. https://doi.org/10.1038/s44264-024-00034-0

Ketchum, D., Hoylman, Z. H., Huntington, J., Brinkerhoff, D., & Jencso, K. G. (2023). Irrigation intensification impacts sustainability of streamflow in the Western United States. *Communications Earth & Environment*, *4*, 479. https://doi.org/10.1038/s43247-023-01152-2

Klinnert, A., Barbosa, A. L., Catarino, R., Fellmann, T., Baldoni, E., Beber, C., Hristov, J., Paracchini, M. L., Rega, C., Weiss, F., Witzke, P., & Rodriguez-Cerezo, E. (2024). Landscape features support natural pest control and farm income when pesticide application is reduced. *Nature Communications*, *15*, 5384. https://doi.org/10.1038/s41467-024-48311-3

Krause, H.-M., Mäder, P., Fliessbach, A., Jarosch, K. A., Oberson, A., & Mayer, J. (2024). Organic cropping systems balance environmental impacts and agricultural production. *Scientific Reports*, *14*, 25537. https://doi.org/10.1038/s41598-024-76776-1

Köninger, J., Labouyrie, M., Ballabio, C., Dulya, O., Mikryukov, V., Romero, F., Franco, A., Bahram, M., Panagos, P., Jones, A., Tedersoo, L., Orgiazzi, A., Briones, M. J. I., & van der Heijden, M. G. A. (2026). Pesticide residues alter taxonomic and functional biodiversity in soils. *Nature*, *650*, 367–373. https://doi.org/10.1038/s41586-025-09991-z

Li, S., Zhuang, Y., Liu, H., Wang, Z., Zhang, F., Lv, M., Zhai, L., Fan, X., Niu, S., Chen, J., Xu, C., Wang, N., Ruan, S., Shen, W., Mi, M., Wu, S., Du, Y., & Zhang, L. (2023). Enhancing rice production sustainability and resilience via reactivating small water bodies for irrigation and drainage. *Nature Communications*, *14*, 3794. https://doi.org/10.1038/s41467-023-39454-w

Mishan, E., & Quah, E. (2007). *Cost–benefit analysis (5th ed.)*. Routledge |.

Naseer, M., Persson, T., Hjelkrem, A.-G. R., Ruoff, P., & Verheul, M. J. (2022). Life cycle assessment of tomato production for different production strategies in Norway. *Journal of Cleaner Production*, *372*, 133659. https://doi.org/10.1016/j.jclepro.2022.133659

Outhwaite, C. L., McCann, P., & Newbold, T. (2022). Agriculture and climate change are reshaping insect biodiversity worldwide. *Nature*, *605*, 97–102. https://doi.org/10.1038/s41586-022-04644-x

Raveloaritiana, E., & Wanger, T. C. (2026). Long-term agricultural diversification increases financial profitability, biodiversity, and ecosystem services: A second-order meta-analysis. *Nature Communications*, *17*, 1016. https://doi.org/10.1038/s41467-025-67757-7

Ricciardi, V., Mehrabi, Z., Wittman, H., James, D., & Ramankutty, N. (2021). Higher yields and more biodiversity on smaller farms. *Nature Sustainability*, *4*, 651–657. https://doi.org/10.1038/s41893-021-00699-2

Schulte-Uebbing, L. F., Beusen, A. H. W., Bouwman, A. F., & de Vries, W. (2022). From planetary to regional boundaries for agricultural nitrogen pollution. *Nature*, *610*, 507–512. https://doi.org/10.1038/s41586-022-05158-2

Srinivasan, K., & Yadav, V. K. (2024). Fresh bell peppers consumed in cities: Unveiling the environmental impact of urban and rural food supply systems. *Science of the Total Environment*, *927*, 172359. https://doi.org/10.1016/j.scitotenv.2024.172359

Suh, D. H., & Moss, C. B. (2021). Examining the input and output linkages in agricultural production systems. *Agriculture*, *11(1)*, 54. https://doi.org/10.3390/agriculture11010054

Tang, F. H. M., Malik, A., Li, M., Lenzen, M., & Maggi, F. (2022). International demand for food and services drives environmental footprints of pesticide use. *Communications Earth & Environment*, *3*, 272. https://doi.org/10.1038/s43247-022-00601-8

Teng, J., Hou, R., Dungait, J. A. J., Zhou, G., Kuzyakov, Y., Zhang, J., Tian, J., Cui, Z., Zhang, F., & Delgado-Baquerizo, M. (2024). Conservation agriculture improves soil health and sustains crop yields after long-term warming. *Nature Communications*, *15*, 8785. https://doi.org/10.1038/s41467-024-53169-6

Tian, X., Zheng, H., Yin, Y., Zhang, Q., He, K., Cong, J., Cai, W., & Cui, Z. (2025). Optimizing nitrogen input to control health and environmental risks in Chinese vegetable production. *Journal of Cleaner Production*, *519*, 145956. https://doi.org/10.1016/j.jclepro.2025.145956

Touch, V., Utomo, A., Harrigan, N., Finlayson, C., McGregor, A., McKinnon, K., Tran, T. A., Bannan, L.-A., Tan, D. K. Y., Sophanara, P., Chay, P., Yous, S., Hainzer, K., & Cook, B. R. (2025). Reshaping agricultural production systems: Trade-offs and implications for sustainable intensification and environment management. *Agricultural Systems*, *230*, 104484. https://doi.org/10.1016/j.agsy.2025.104484

Wang, X., Cheng, J., Zhang, J., & Chen, F. (2024). Influences of crop diversification on yield, resource use efficiency, and environmental footprint in farmland landscapes in intensive farming. *Science of the Total Environment*, *945*, 174009. https://doi.org/10.1016/j.scitotenv.2024.174009

Zhang, T., Jia, Y., Ren, K., Wang, S., Li, Z., Chen, W., & Hong, J. (2024). Environmental–economic total factor productivity of vegetable production in China from the life cycle perspective. *Journal of Cleaner Production*, *477*, 143806. https://doi.org/10.1016/j.jclepro.2024.143806

Zhang, Y., Bohan, D. A., Zhang, C., Cong, W.-F., Munier-Jolain, N., & Bedoussac, L. (2025). Crop diversity reduces pesticide use more efficiently with refined diversification strategies. *Communications Earth & Environment*, *6*, 460. https://doi.org/10.1038/s43247-025-02418-7