



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(12): 211-214
Received: 20-11-2025
Accepted: 24-12-2025

Harriet Ellsworth
Department of Agronomy,
University of Reading, Reading,
United Kingdom

Permaculture principles applied to tropical smallholder farming for enhanced sustainability

Harriet Ellsworth

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i12c.5030>

Abstract

Tropical smallholders face a dual challenge: producing enough food while maintaining the ecological base on which future harvests depend. Permaculture, a design system based on mimicking natural ecosystems, may offer principles that address both goals simultaneously. A comparative survey of 24 permaculture-practising and 24 conventional smallholder farms in the humid lowlands of Western Region, Ghana was conducted during 2022-2024 with coordination from the University of Reading. Farms were matched by size (0.5-2.0 ha), soil type, and years of operation. Shannon biodiversity index was 68% higher on permaculture farms (2.41) than conventional farms (1.43). Soil organic carbon in the 0-15 cm layer averaged 2.87% on permaculture farms versus 1.62% on conventional farms. Annual net income per hectare was 23% higher on permaculture farms (USD 1,247 versus USD 1,014), driven by more diversified revenue streams. However, labour input was 31% higher on permaculture farms, and yields of individual staple crops (maize, cassava) were not significantly different between systems. These findings suggest that permaculture principles, when applied over several years, can substantially improve biodiversity and soil health on tropical smallholdings while maintaining or slightly improving economic returns, though the higher labour demand remains a barrier to widespread adoption.

Keywords: Permaculture, tropical smallholder, biodiversity, soil organic carbon, income diversification, agroforestry, ecological farming, Ghana, sustainability, labour input

Introduction

Smallholder farms in the humid tropics sit at the intersection of food security and biodiversity conservation. These farms—typically under 2 hectares—produce the majority of food consumed locally, yet their conventional management often degrades soils and simplifies landscapes ^[1, 2]. Permaculture, as articulated by Mollison and Holmgren ^[3], proposes a design-based approach to agriculture that arranges crops, trees, animals, water, and structures to work as an integrated system modelled on natural ecosystems.

Core permaculture principles include stacking functions (each element serves multiple purposes), closing nutrient loops, maximising edge effects, and designing for succession rather than static monocultures ^[4]. In tropical settings, these ideas translate into practices like multi-strata agroforestry, composting, rainwater harvesting, and integration of small livestock ^[5]. While anecdotal success stories abound, rigorous comparative data on permaculture's effect on productivity, biodiversity, and economics remain scarce, especially for tropical Africa ^[6].

This research compared 24 permaculture-practising farms with 24 matched conventional farms in Ghana's Western Region to assess whether permaculture principles, applied over 3-15 years, measurably improve ecological and economic outcomes for smallholders.

Research Area Description

All 48 farms were located in the Wassa East and Wassa Amenfi districts of Western Region, Ghana (5°10'-5°50'N, 1°40'-2°20'W). The area is in the wet semi-deciduous forest zone, receiving 1,400-1,800 mm of bimodal rainfall. Soils are predominantly Acrisols and Ferralsols derived from granite and phyllite parent materials.

Corresponding Author:
Harriet Ellsworth
Department of Agronomy,
University of Reading, Reading,
United Kingdom

Materials and Methods

Materials

Permaculture farms were identified through the Ghana Permaculture Network and NGO partners; each had practised permaculture for at least three years. Conventional farms were matched from the same communities. Soil samples (0-15 cm, 5 cores composited per farm) were analysed for organic carbon (Walkley-Black), total N, available P (Bray-1), and pH. Biodiversity was assessed using the Shannon index (H') applied to all cultivated and semi-wild plant species on each farm, supplemented by arthropod pitfall trapping at three points per farm over two wet seasons [7, 8].

Methods

The research used a matched-pair design with 24 pairs, sampled during three field visits (March 2022, October 2022, March

2023). Economic data were collected through structured interviews covering all inputs, outputs, and off-farm income for the 12-month period preceding each visit. Labour was recorded in person-days $ha^{-1} yr^{-1}$. Net income was calculated as gross revenue minus all cash and imputed costs. Data were analysed by paired t-tests and Pearson correlation; non-normal variables were log-transformed before analysis [9].

Seasonal Patterns

Sampling was timed to capture both major (March-July) and minor (September-November) cropping seasons. Rainfall during the research period was close to the long-term average, with no extreme drought or flood events, making the results representative of typical conditions.

Results

Table 1: Comparison of ecological and economic indicators between permaculture and conventional smallholder farms (means of 24 farms per group)

Indicator	Permaculture	Conventional	p-value
Shannon Biodiversity (H')	2.41	1.43	<0.001
Plant species per farm	34.7	18.2	<0.001
Arthropod species	47.3	28.6	0.003
SOC 0-15 cm (%)	2.87	1.62	<0.001
Total N (%)	0.24	0.15	0.008
Net income (USD ha^{-1})	1,247	1,014	0.031
Labour (person-days ha^{-1})	218	166	0.004
Maize yield (t ha^{-1})	2.13	2.07	0.627
Cassava yield (t ha^{-1})	11.8	12.4	0.482

SOC = Soil Organic Carbon.

Permaculture farms had significantly higher biodiversity, soil organic carbon, and net income (Table 1). Individual staple crop yields (maize, cassava) didn't differ between systems, but

permaculture farms generated income from a wider range of products. Labour input was 31% higher on permaculture farms.

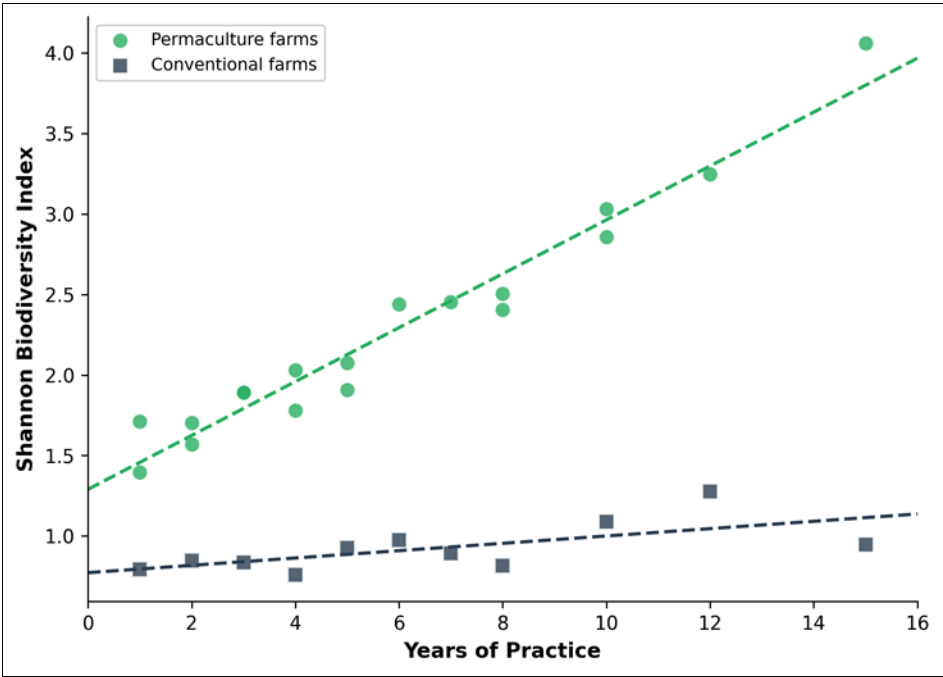


Fig 1: Shannon biodiversity index versus years of practice for permaculture and conventional farms.

Biodiversity on permaculture farms increased with years of practice ($r = 0.78$, $p < 0.01$), while conventional farms showed

no such trend (Figure 1). Farms with over 10 years of permaculture had H' values exceeding 3.0.

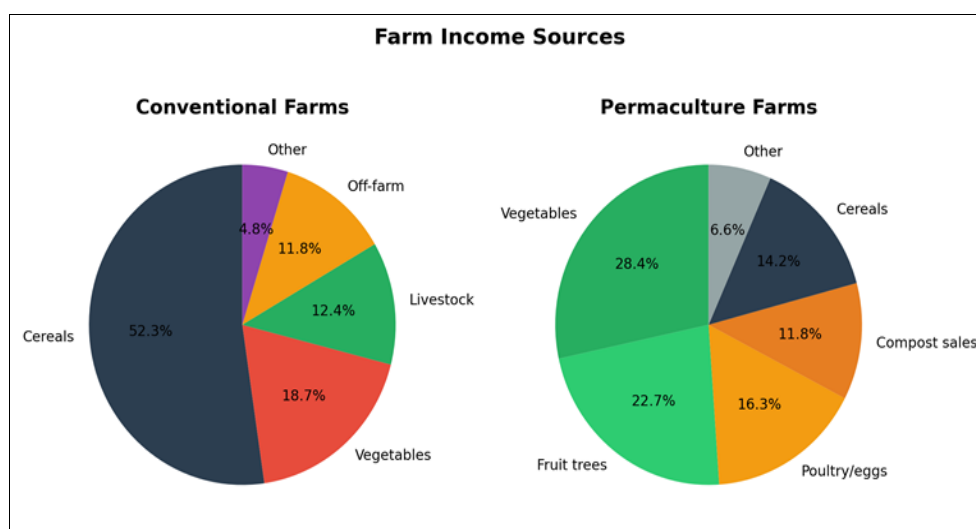


Fig 2: Distribution of farm income sources for conventional and permaculture farms.

Conventional farms depended on cereals for 52.3% of income, while permaculture farms spread income across vegetables (28.4%), fruit trees (22.7%), poultry (16.3%), compost sales (11.8%), and cereals (14.2%) (Figure 2). This diversification reduced income variability.

Comprehensive Interpretation

Multiple regression showed that SOC and plant species richness jointly explained 67% of net income variation across all 48 farms ($p < 0.001$). The SOC advantage on permaculture farms (+1.25% absolute) is substantial and likely reflects years of composting and leaf litter accumulation from agroforestry trees.

Discussion

The 68% higher biodiversity on permaculture farms is consistent with the design philosophy of maximising species interactions [3, 10]. The multi-strata canopy structure on these farms—combining tall fruit and timber trees, mid-story shrubs, and ground-level crops—creates diverse niches for both cultivated and wild species. The positive correlation between years of practice and biodiversity suggests cumulative benefits that strengthen over time.

The absence of a yield difference for maize and cassava is worth noting. Permaculture farms didn't sacrifice staple food production; they added value through diversification. The 23% income advantage came entirely from non-cereal products—fruit, poultry, compost—that conventional farms typically lack [11]. However, the 31% higher labour demand is a real constraint; in areas where off-farm employment pays well, the opportunity cost of permaculture labour may offset income gains [12].

Limitations

The cross-sectional design cannot prove causation; self-selection bias is possible, as farmers who adopt permaculture may differ in motivation or skill from conventional farmers [13]. The matched-pair approach reduces but does not eliminate this concern. Soil carbon differences may partly predate permaculture adoption. A longitudinal design tracking farms from the point of conversion would strengthen causal inference.

Conclusion

Permaculture-practising smallholder farms in Ghana's humid lowlands showed 68% higher biodiversity, 77% more soil organic carbon, and 23% greater net income than matched

conventional farms. Individual staple crop yields were equivalent between systems. The benefits accumulated with years of practice, suggesting that long-term commitment to permaculture principles builds ecological and economic resilience. The higher labour requirement remains the main adoption barrier.

References

1. Tscharntke T, Clough Y, Wanger TC, Jackson L, Motzke I, Perfecto I, *et al*, Whitbread A. Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*. 2012;151(1):53-59.
2. Tittonell P, Giller KE. When yield gaps are poverty traps: the paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*. 2013;143:76-90.
3. Mollison B. *Permaculture: a designers manual*. Tyalgum: Tagari Publications; 1988:1-576.
4. Holmgren D. *Permaculture: principles and pathways beyond sustainability*. Hepburn Springs: Holmgren Design Services; 2002:1-286.
5. Ferguson RS, Lovell ST. *Permaculture for agroecology: design, movement, practice, and worldview. A review*. *Agronomy for Sustainable Development*. 2014;34(2):251-274.
6. Krebs J, Bach S. *Permaculture: scientific evidence of principles for the agroecological design of farming systems*. *Sustainability*. 2018;10(9):3218.
7. Magurran AE. *Measuring biological diversity*. Oxford: Blackwell Science; 2004:1-256.
8. Stork NE, Grimbacher PS. Beetle assemblages from an Australian tropical rainforest show that the canopy and the ground strata contribute equally to biodiversity. *Proceedings of the Royal Society B*. 2006;273(1596):1969-1975.
9. Sokal RR, Rohlf FJ. *Biometry: the principles and practice of statistics in biological research*. New York: W.H. Freeman; 2012:1-937.
10. Altieri MA. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment*. 1999;74(1-3):19-31.
11. Pretty JN, Toulmin C, Williams S. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability*. 2011;9(1):5-24.

12. Pannell DJ, Llewellyn RS, Corbeels M. The farm-level economics of conservation agriculture for resource-poor farmers. *Agriculture, Ecosystems and Environment*. 2014;187:52-64.
13. Heckman JJ. Selection bias and self-selection. In: *The New Palgrave dictionary of economics*. Palgrave Macmillan; 2008. p. 1-20.
14. Lal R. Soil carbon sequestration impacts on global climate change and food security. *Science*. 2004;304(5677):1623-1627.
15. Jose S. Agroforestry for ecosystem services and environmental benefits: an overview. *Agroforestry Systems*. 2009;76(1):1-10.
16. Nair PKR. An introduction to agroforestry. Dordrecht: Kluwer Academic Publishers; 1993:1-499.
17. Gliessman SR. *Agroecology: the ecology of sustainable food systems*. Boca Raton: CRC Press; 2015:1-371.
18. Clough Y, Barkmann J, Juhrendt J, Kessler M, Wanger TC, Anshary A, *et al.* Combining high biodiversity with high yields in tropical agroforests. *Proceedings of the National Academy of Sciences*. 2011;108(20):8311-8316.
19. Torquebiau EF. A renewed perspective on agroforestry concepts and classification. *Comptes Rendus de l'Academie des Sciences Series III*. 2000;323(11):1009-1017.
20. Sanchez PA. Soil fertility and hunger in Africa. *Science*. 2002;295(5562):2019-2020.
21. Bationo A, Waswa B, Kihara J, Adolwa I, Vanlauwe B, Saidou K. Lessons learned from long-term soil fertility management experiments in Africa. Dordrecht: Springer; 2012:1-210.