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Impact of Intercropping Practices on Farm Productivity and Household Welfare in Ghana

Kwame Ansah Baffour[1],[2], Camillus Abawiera Wongnaa[1] and Dadson Awunyo-Vitor[1]

[1] Kwame Nkrumah University of Science and Technology, Department of Agricultural Economics, Agribusiness and Extension, Kumasi, Ghana

[2] Kwadaso Agricultural College, Kwadaso, Kumasi, Ghana

Abstract

Intercropping is widely promoted as a sustainable intensification strategy, yet evidence on whether productivity gains translate into household welfare remains limited and crop-system specific. This study examines cereal-legume, cereal-tuber, cereal-tree/perennial and legume-root/tuber intercropping in Ghana using Waves 2 and 3 of the Ghana Socioeconomic Panel Survey, a longitudinal household survey conducted through a collaboration involving Yale University, Northwestern University and University of Ghana, Legon. Fixed-effects models, inverse-probability-weighted regression adjustment (IPWRA) and endogenous switching regression address household heterogeneity and non-random adoption. Mean log yield is significantly higher under all four systems, and IPWRA indicates substantial productivity gains. Welfare transmission is heterogeneous: gross-profit advantages are concentrated in cereal-tree/perennial and cereal-tuber systems and food-consumption differences are not statistically significant, but household dietary diversity scores (HDDS) are significantly higher for cereal-legume (+0.234), cereal-tuber (+0.892) and cereal-tree/perennial (+1.040); the legume-root/tuber difference (+0.062) is not significant. Intercropping can therefore strengthen productivity and dietary quality, although effects depend on crop combination and market conditions.

Keywords: dietary diversity; farm productivity; Ghana; household welfare; intercropping; IPWRA; smallholder agriculture

*Corresponding author: kwameansahbaffour@gmail.com

Introduction

Smallholder agriculture in Ghana is constrained by declining soil fertility, fragmented landholdings, limited access to improved inputs and finance, and exposure to rainfall and market uncertainty. Intercropping - the simultaneous cultivation of two or more crop species on the same land - can contribute to sustainable intensification by exploiting complementarities in canopy structure, rooting depth, nutrient acquisition and growing periods. Cereal-legume systems may additionally benefit from biological nitrogen fixation, while tree-based and root/tuber combinations can diversify output and income streams. Meta-analytical and field evidence shows that well-managed intercrops can improve land productivity and resource-use efficiency, although effects depend strongly on crop combination and management (Feng et al., 2021; Namatsheve et al., 2021; Mugi-Ngenga et al., 2023).

Evidence from smallholder fields is nevertheless mixed. Intercropping may raise combined output while increasing labour requirements or reducing the yield of an individual component crop (Madembo et al., 2020; Li et al., 2023). More importantly, higher biological productivity does not necessarily translate into higher profits or household consumption.

Existing studies also often treat intercropping as a homogeneous practice, masking differences among crop combinations. This study therefore estimates the productivity and welfare implications of four major systems in Ghana: cereal-legume (CL), cereal-tuber (CT), cereal-tree crop (CTree) and legume-root/tuber (LR), each compared with its relevant monocropping counterfactual.

Methodology

The study draws on Waves 2 (2013/2014) and 3 (2018/2019) of the Ghana Socioeconomic Panel Survey (GSPS), a longitudinal household survey conducted through a collaboration involving the Economic Growth Center at Yale University, the Global Poverty Research Lab at Northwestern University, and the Institute of Statistical, Social and Economic Research (ISSER) at the University of Ghana, Legon. The analytical panel comprises 5,729 farm-plot observations associated with 4,156 household identifiers. Based on the crop combinations identified in the survey data, four intercropping systems were classified: cereal–legume (CL), cereal–tuber (CT), cereal–tree/perennial (CTree), and legume–root/tuber (LR). Each intercropping system was evaluated relative to its corresponding monocropping reference group to assess differences in farm productivity and household welfare. Table 1 presents the crop categories and constituent crops used to define the four intercropping systems.

Table 1. Crop classification used to construct intercropping systems

Crop category	Crops observed in analytical data	System
Cereals	Sorghum/Guinea corn; maize; millet; rice	CL, CT, CTree
Legumes	Beans/peas; groundnut; soya beans	CL, LR
Roots & tubers	Cassava; cocoyam; yam	CT, LR
Tree/perennial	Avocado; cashew; cocoa; mango; oil palm; orange; pawpaw; plantain; rubber	CTree

Farm productivity is measured as log yield, based on total harvested output per hectare. Household welfare is assessed using gross profit per hectare, annual food-consumption expenditure and the Household Dietary Diversity Score (HDDS), which complements expenditure-based welfare with a dietary-quality dimension. Covariates include farmer age, education, farming experience and gender, cultivated land, soil-management index, household assets, rainfall and survey-wave effects. Because adoption is non-random, simple mean comparisons may confound treatment effects with differences in resource endowments, agroecology and management.

The empirical strategy combines fixed-effects (FE) models, inverse-probability-weighted regression adjustment (IPWRA) and endogenous switching regression (ESR). FE models control for time-invariant household heterogeneity. IPWRA combines a treatment model with outcome regression and is doubly robust when either component is correctly specified; its average treatment effect on the treated (ATET) is used as the principal productivity benchmark. ESR estimates regime-specific outcome equations and counterfactual outcomes to assess selection on unobservables. Robust standard errors are clustered at household level where applicable. Welfare results are kept consistent with the completed estimates and are interpreted cautiously where only mean-comparison evidence is available.

Results and Discussion

Adoption differed substantially across systems. Across the two waves, CT recorded the largest number of adopters (651), followed by CL (589), LR (221) and CTree (198). The classification links cereals with legumes, roots/tubers, or tree/perennial crops as detailed in Table 1. Mean comparisons show significantly higher log yield under all four intercrops. Intercroppers also tended to cultivate larger farms and record higher soil-management indices, supporting the use of treatment-effect and panel estimators rather than raw means alone.

Table 2. Selected productivity and household welfare results by intercropping system

System	Mean log-yield diff.[1]	IPWRA ATET[2]	Gross-profit diff.[1]	Food-consumption diff.[1]	HDDS diff.[1]
CL	0.533***	0.814***	528.11	897.26	0.234***
CT	0.188**	0.517***	4,655.70*	416.00	0.892***
CTree	0.677***	1.316***	3,164.84***	1,299.67	1.040***
LR	0.829***	1.036***	1,225.24	-3,746.65	0.062

Notes: [1] Difference = intercropping minus monocropping; positive values indicate higher means among intercroppers. Monetary differences are in USD, converted using the 2019 annual-average exchange rate of GHS 5.36/US$1. [2] ATET is in log-yield units. *** p<0.01, ** p<0.05, * p<0.10.

The IPWRA estimates reinforce the productivity advantage after adjustment for observable selection. ATETs are 0.814 for CL, 0.517 for CT, 1.316 for CTree and 1.036 for LR (all $p<0.01$), implying large gains among adopters relative to their estimated monocropping counterfactuals. The particularly strong CTree and LR effects underscore the importance of crop-specific biological complementarity. ESR results generally support substantial treatment effects, although several ESR magnitudes are larger and diagnostics differ across systems; IPWRA is therefore emphasized as the more conservative benchmark.

The results are consistent with biological complementarity as an important mechanism. Legume-based systems can improve nitrogen availability and resource capture, while crop mixtures with contrasting rooting and canopy structures can use land, water and light more efficiently. This accords with evidence that maize-peanut and maize-cowpea intercrops can raise land productivity and system performance (Feng et al., 2021; Namatsheve et al., 2021). At the same time, the heterogeneity across Ghanaian systems supports the argument that intercropping should not be treated as a single technology. Crop choice, water competition and management determine whether complementarity dominates competition (Mugi-Ngenga et al., 2023).

Economic and welfare outcomes are more nuanced than the productivity results. Gross profit per hectare is significantly higher for CT and especially CTree, whereas CL and LR differences are not statistically significant. Food-consumption expenditure shows no statistically significant difference for any system. HDDS, however, reveals an important welfare channel: relative to monocropping, dietary diversity is higher by 0.234 food groups for CL ($p<0.01$), 0.892 for CT ($p<0.01$) and 1.040 for CTree ($p<0.01$). The LR difference is positive (0.062) but statistically insignificant. Intercropping may therefore improve household dietary quality even where expenditure effects are weak, plausibly because diversified production broadens access to different food groups directly or through income and market pathways.

The findings also have an adoption dimension. Intercropping farmers generally operate larger farms and use better soil-management practices, while education, farming experience, assets and institutional participation vary by crop combination. CTree appears relatively knowledge- and capital-intensive, whereas legume-based systems are more accessible to resource-constrained farmers. Rainfall differs significantly across production systems, underscoring the importance of controlling for agroecological conditions. These patterns imply that scaling intercropping requires system-specific extension and resource support rather than a uniform recommendation.

The robustness evidence also cautions against interpreting a single estimator mechanically. Fixed-effects results for some systems remain positive but are less precise because identification comes from within-household changes over only two survey waves. ESR can address selection on unobservables, yet several estimated counterfactual effects are much larger than the corresponding IPWRA effects and are sensitive to the strength of exclusion restrictions and regime specification.

The convergence of signs across descriptive, FE and IPWRA results is therefore more informative than any single very large percentage estimate. In this study, the IPWRA estimates are emphasized because they provide a conservative, transparent treatment-effect benchmark after balancing observed characteristics, while ESR is used as complementary evidence on selection. This interpretation is particularly important for heterogeneous smallholder systems in which land size, rainfall, management ability and crop choice jointly shape both adoption and outcomes.

From a multifunctional agro-ecosystem perspective, intercropping can support land productivity, crop diversification, dietary quality and sustainable soil management, but household-level benefits depend on the production system and institutional environment. The HDDS gains for CL, CT and CTree show that welfare assessment based only on food expenditure would miss an important nutrition-related dimension. Extension programmes should match crop combinations to agroecological conditions and household objectives, while market interventions reduce transaction costs that can prevent additional output from becoming disposable income.

Conclusions and Outlook

Intercropping is associated with substantial productivity gains in Ghana, but the magnitude and welfare transmission differ across crop combinations. IPWRA estimates are positive and highly significant for CL, CT, CTree and LR, while descriptive evidence shows higher mean yields for all four systems. Profitability gains are clearest for CTree and weaker for CT, and food-consumption expenditure is not significantly different across the four comparisons. Importantly, HDDS is significantly higher under CL, CT and CTree, with the largest dietary-diversity gain under CTree; LR shows a small, statistically insignificant increase. These results indicate that intercropping can improve dietary quality even when short-run expenditure responses are limited.

Policy and extension programmes should promote intercropping as a portfolio of context-specific technologies. Agronomic advice should explicitly consider the component crops identified in the data - cereals, legumes, roots/tubers and tree/perennial crops - together with spacing, soil management, extension, credit, climate information and output markets. Future work should estimate comparable causal treatment effects for gross profit, food consumption and HDDS across all systems and examine whether welfare effects strengthen over longer periods.

References

Aboah, J. & Setsoafia, E.D. (2022). Examining the synergistic effect of cocoa-plantain intercropping system on gross margin: A system dynamics modelling approach. Agricultural Systems 195, 103301.

Curtright, A.J. & Tiemann, L.K. (2021). Intercropping increases soil extracellular enzyme activity: A meta-analysis. Agriculture, Ecosystems & Environment 319, 107489.

Feng, C. et al. (2021). Maize/peanut intercropping increases land productivity: A meta-analysis. Field Crops Research 270, 108208.

Gu, C. et al. (2021). Annual intercropping suppresses weeds: A meta-analysis. Agriculture, Ecosystems & Environment 322, 107658.

Li, C. et al. (2023). Limited environmental and yield benefits of intercropping practices in smallholder fields: Evidence from multi-source data. Field Crops Research 299, 108974.

Madembo, C., Mhlanga, B. & Thierfelder, C. (2020). Productivity or stability? Exploring maize-legume intercropping strategies for smallholder conservation-agriculture farmers in Zimbabwe. Agricultural Systems 185, 102921.

Mugi-Ngenga, E. et al. (2023). The role of inter-specific competition for water in maize-legume intercropping systems in northern Tanzania. Agricultural Systems 207, 103619.

Namatsheve, T. et al. (2021). Maize-cowpea intercropping as an ecological intensification option for low-input systems in sub-humid Zimbabwe. Field Crops Research 263, 108052.