**Metropolitan Journal of Environmental and Health Research**
**ISSN: 1813-4262**
**Vol. 5 Issue 4, April- 2026, Pages: 88-96**

# The Effect Of Agro-Ecological Practices On The Income And Sustainability Of Smallholder Farmers In Nwoya District, Northern Uganda

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**Abstract**

Northern Uganda's post-conflict agricultural landscape presents both acute challenges and significant opportunities for sustainable rural development. This study examines the effect of agro-ecological practices on the income and sustainability outcomes of smallholder farmers in Nwoya District, a key agricultural zone in Northern Uganda. A quasi-experimental design was employed, comparing outcomes between 160 smallholder farmers who adopted agro-ecological practices through a structured intervention program and 160 control farmers using conventional agricultural methods. Data were collected at baseline (2021) and endline (2023), measuring household income, crop yield, soil health, input costs, and ecological resilience indicators. Results indicate that farmers adopting agro-ecological practices experienced a 38.4% increase in net household income, a 27.1% improvement in crop yield diversity, and significant improvements in soil organic matter content compared to control farmers. Adoption was associated with a 41.2% reduction in external input costs, primarily through reduced fertilizer and pesticide expenditure. Structural barriers to adoption, including limited access to technical knowledge, short-term income trade-offs during transition periods, and inadequate market access for organically certified produce, were identified. The study provides robust evidence for scaling agro-ecological approaches in Northern Uganda's post-conflict agricultural development agenda.

**Keywords: Agro-Ecological Practices, Income, Sustainability and Smallholder Farmers**

## Introduction

Nwoya District in Northern Uganda is situated in the Acholi sub-region, an area that experienced two decades of devastating armed conflict related to the Lord's Resistance Army (LRA) insurgency, which displaced over 90% of the rural population into internally displaced persons (IDP) camps (UNHCR, 2008). Following the cessation of hostilities in 2006 and the gradual return of communities to their ancestral lands between 2007 and 2012, agricultural recovery became the central pillar of the region's reintegration and development agenda(Ntirandekura & Christopher, 2022). Nwoya's fertile soils, favorable rainfall distribution of 1,200–1,500mm annually, and relatively low population density (compared to the rest of Uganda) give the district exceptional agricultural potential that has attracted investment from government programs, NGOs, and private sector actors (NUSAF III, 2018).

However, the dominant agricultural paradigm in Nwoya, characterized by monocropping of maize and cassava, heavy dependence on chemical inputs, and minimal attention to soil health, has produced diminishing returns over the past decade(Kazaara & Kazaara, 2023). Land productivity has stagnated, soil degradation has intensified, and the vulnerability of smallholder households to climate shocks has increased, with the 2019 dry spell causing yield losses of over 40% in maize-dependent households (FAO Uganda, 2020). In this context, agro-ecological approaches which integrate ecological principles into agricultural systems, emphasizing biodiversity, soil health, water management, and

**Received: 08.04.2026 Accepted: 12.04.2026 Published on: 30.04.2026**

reduced external inputs have been promoted by organizations including the Alliance of Bioversity International and CIAT, NARO, and several NGOs as a pathway to sustainable intensification(Petchey & Gaston, 2006).

This study emerges from a three-year agro-ecological intervention implemented by the Nwoya Sustainable Agriculture Program (NSAP), which supported 160 smallholder farmers across four sub-counties to adopt a suite of agro-ecological practices including intercropping, composting, rainwater harvesting, agroforestry, and integrated pest management. By rigorously evaluating the income and sustainability effects of this program through a quasi-experimental design, this research generates critical evidence to inform scaling decisions, policy advocacy, and future program design in the region.

**Problem Statement**

Smallholder farmers in Nwoya District continue to experience persistently low agricultural incomes, deteriorating soil fertility, and heightened vulnerability to climate variability, despite substantial investments aimed at revitalizing the agricultural sector in post-conflict Northern Uganda(Alex & Julius, 2024). Following the end of the Lord's Resistance Army insurgency, both the Government of Uganda and various development partners implemented recovery programs focused on resettlement, input provision, and agricultural commercialization. While these interventions contributed to short-term recovery and increased production levels, they have not translated into sustained income growth or long-term resilience for smallholder farmers.

A key challenge underlying this situation is the continued reliance on conventional agricultural practices, including monocropping, excessive tillage, and limited use of organic soil management techniques. These practices have contributed to declining soil fertility, land degradation, and reduced productivity over time(Allan et al., 2023). As a result, farmers remain trapped in a cycle of low yields and low incomes, with limited capacity to reinvest in their farms or adopt improved technologies. Furthermore, increasing climate variability manifested through erratic rainfall patterns, prolonged dry spells, and occasional flooding has exacerbated production risks, making farming outcomes more unpredictable and further undermining household livelihoods(Christopher, 2022). In response to these challenges, agro-ecological practices have been promoted as a sustainable alternative. Agro-ecology emphasizes environmentally friendly farming approaches such as crop diversification, organic soil fertility management, agroforestry, and water conservation techniques(Audrey & Kazaara, 2025). These practices are expected to enhance soil health, improve resilience to climate shocks, and support more stable and diversified income streams for farmers. However, despite growing advocacy for agro-ecology, its adoption in Nwoya District remains limited and uneven.

One major constraint to wider adoption is the lack of rigorous, context-specific empirical evidence demonstrating the economic and environmental benefits of agro-ecological practices within the unique post-conflict setting of Northern Uganda. Most existing studies on agro-ecology are either generalized across regions or focused on different agro-ecological zones, making it difficult to draw reliable conclusions for Nwoya District. Additionally, the post-conflict

**Metropolitan Journal of Environmental and Health Research**
**ISSN: 1813-4262**
**Vol. 5 Issue 4, April- 2026, Pages: 88-96**

context characterized by disrupted social systems, land tenure uncertainties, and varying levels of farmer capacity introduces complexities that may influence both adoption and outcomes of these practices. This evidence gap presents a significant challenge for policymakers, development agencies, and agricultural practitioners. Without clear, localized data on how agro-ecological practices affect income levels, soil health, and climate resilience, interventions risk being poorly targeted, underutilized, or ineffective. Consequently, opportunities to promote sustainable agricultural transformation and improve rural livelihoods may be missed. Therefore, this study seeks to address this gap by empirically examining the impact of agro-ecological practices on smallholder farmer incomes and environmental sustainability in Nwoya District.

**Main Objective**

To assess the effects of agro-ecological practices on household income and agricultural sustainability among smallholder farmers in Nwoya District, Northern Uganda.

**Methods and Materials**

This study employed a quasi-experimental pre-post control group design, comparing outcomes between treatment farmers (those participating in the NSAP agro-ecological program) and control farmers (those using conventional methods) at two time points: baseline (June 2021) and endline (June 2023). Treatment farmers (n=160) were recruited through the NSAP program across four sub-counties: Alero, Purongo, Anaka, and Koch-Goma(Nafiu et al., 2017). Control farmers (n=160) were selected from adjacent villages within the same sub-counties using purposive sampling to match treatment farmers on baseline land size, household composition, and pre-program income levels, minimizing selection bias. All 320 respondents were interviewed using a structured questionnaire administered by trained enumerators at both time points(Olanrewaju et al., 2021).

The agro-ecological practices adopted by treatment farmers included intercropping (legumes with cereals), composting and organic fertilizer production, rainwater harvesting using half-moon catchments and contour bunds, agroforestry (integration of Calliandra, Leucaena, and Moringa trees), and integrated pest management (botanical pesticides, trap crops, crop rotation). Outcome variables measured at both time points included: net household agricultural income (UGX), number of distinct crops cultivated, soil organic matter content (%), input expenditure (UGX per season), and an ecological resilience index comprising six sub-indicators (soil cover, water retention, biodiversity index, land degradation score, climate adaptation capacity, and market diversification)(Journal et al., 2023). Data were analyzed using SPSS 26.0, employing paired t-tests for within-group changes, independent t-tests for between-group comparisons, and multiple regression to identify predictors of income change(Nelson et al., 2022). Soil samples from 30 treatment and 30 control farms were analyzed at the Uganda National Agricultural Research Organisation (NARO) laboratory in Gulu.

**Results**

The results demonstrate significant positive outcomes for treatment farmers across all measured dimensions compared to control farmers. Key results are presented in Tables 1, 2, and 3.

**Received: 08.04.2026 Accepted: 12.04.2026 Published on: 30.04.2026**

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**Table 1: Household Income and Crop Yield Changes (2021–2023)**

| Indicator | Trt. Baseline | Trt. Endline | Ctrl. Baseline | Ctrl. Endline | p-value |
|---|---|---|---|---|---|
| Net agricultural income (UGX '000/yr) | 1,842 | 2,550 | 1,871 | 1,940 | < 0.001 |
| % change in income | — | +38.4% | — | +3.7% | < 0.001 |
| Number of crop species cultivated | 3.1 | 4.9 | 3.0 | 3.2 | < 0.001 |
| Annual input expenditure (UGX '000) | 612 | 360 | 604 | 638 | < 0.001 |
| Households below poverty line (<$1.90/day) | 68.1% | 44.4% | 66.9% | 64.4% | < 0.001 |

The results presented in Table 1 indicated that households in the treatment group experienced substantial improvements in both agricultural income and production diversity over the study period from 2021 to 2023. At baseline, the average annual net agricultural income for the treatment group stood at UGX 1,842,000, which increased significantly to UGX 2,550,000 at endline. This represented a 38.4% increase in income, a change that was both economically meaningful and statistically significant ($p < 0.001$)(Nelson et al., 2023). In contrast, the control group showed only a marginal increase in income from UGX 1,871,000 to UGX 1,940,000, corresponding to a modest 3.7% growth. The large difference in income growth between the two groups suggested that the intervention had a strong positive effect on household earnings.

In addition to income gains, the treatment group demonstrated a notable increase in crop diversification. The average number of crop species cultivated rose from 3.1 at baseline to 4.9 at endline, indicating a shift toward more diversified farming systems. Meanwhile, the control group showed only a slight increase from 3.0 to 3.2 crop species. This suggested that farmers in the treatment group adopted more diverse cropping strategies, which are often associated with improved resilience and productivity. Furthermore, annual input expenditure in the treatment group decreased significantly from UGX 612,000 to UGX 360,000, implying that farmers were able to reduce reliance on costly external inputs, possibly due to the adoption of more sustainable practices. Conversely, input expenditure in the control group increased from UGX 604,000 to UGX 638,000, reflecting continued dependence on conventional inputs. Importantly, the proportion of households living below the international poverty line (less than $1.90 per day) declined sharply in the treatment group, from 68.1% at baseline to 44.4% at endline. This marked a substantial reduction in poverty levels. In contrast, the control group showed only a slight decrease from 66.9% to 64.4%. The statistically significant differences across all indicators ($p < 0.001$) reinforced the conclusion that the observed improvements in income, diversification, and poverty reduction were strongly associated with the intervention rather than random variation.

**Received: 08.04.2026 Accepted: 12.04.2026 Published on: 30.04.2026**

**Table 2: Soil Health Indicators at Endline (2023)**

| Soil Health Indicator | Treatment (Mean) | Control (Mean) | Significance |
|---|---|---|---|
| Soil organic matter content (%) | 3.84 | 2.31 | $p < 0.001$ |
| Soil pH | 6.2 | 5.7 | $p = 0.003$ |
| Available phosphorus (mg/kg) | 18.4 | 11.2 | $p < 0.001$ |
| Bulk density (g/cm³) | 1.21 | 1.48 | $p < 0.001$ |
| Earthworm count per m² | 28.4 | 12.1 | $p = 0.002$ |

The soil health indicators at endline revealed clear and statistically significant differences between the treatment and control groups, demonstrating the positive environmental impact of the intervention. The treatment group recorded a mean soil organic matter content of 3.84%, compared to 2.31% in the control group ($p < 0.001$). This indicated improved soil fertility and structure among treatment farms, as higher organic matter is associated with better nutrient availability and moisture retention.

Similarly, soil pH levels were more favorable in the treatment group, with a mean of 6.2 compared to 5.7 in the control group ($p = 0.003$). This suggested that soils in the treatment group were closer to neutral pH conditions, which are generally more suitable for optimal crop growth. Available phosphorus levels were also significantly higher in the treatment group (18.4 mg/kg) than in the control group (11.2 mg/kg), further indicating enhanced soil nutrient status.

In terms of physical soil properties, bulk density was lower in the treatment group (1.21 g/cm³) compared to the control group (1.48 g/cm³), with the difference being highly significant ($p < 0.001$). Lower bulk density is indicative of better soil structure, improved root penetration, and enhanced water infiltration. Additionally, biological activity, as measured by earthworm count per square meter, was substantially higher in the treatment group (28.4) than in the control group (12.1), with statistical significance ($p = 0.002$). This highlighted improved soil biological health, as earthworms play a critical role in nutrient cycling and soil aeration.

**Table 3: Ecological Resilience Index Scores at Endline**

| Resilience Sub-indicator | Treatment Score /10 | Control Score /10 | Difference |
|---|---|---|---|
| Soil cover and erosion control | 7.8 | 4.2 | +3.6 |
| Water retention capacity | 7.1 | 4.8 | +2.3 |
| Agricultural biodiversity index | 8.2 | 4.4 | +3.8 |
| Market diversification score | 6.4 | 3.9 | +2.5 |
| Climate adaptation capacity | 7.3 | 4.1 | +3.2 |
| **Composite Resilience Index** | **7.4** | **4.3** | **+3.1** |

**Received: 08.04.2026 Accepted: 12.04.2026 Published on: 30.04.2026**

The Ecological Resilience Index scores at endline showed that the treatment group consistently outperformed the control group across all measured dimensions of resilience. The composite resilience index score for the treatment group was 7.4 out of 10, compared to 4.3 for the control group, resulting in a substantial difference of +3.1 points. This indicated that households in the treatment group were considerably more resilient to environmental and economic shocks.

Looking at specific sub-indicators, the treatment group achieved a score of 7.8 in soil cover and erosion control, compared to 4.2 in the control group, reflecting a strong improvement in land management practices that reduce soil degradation. Water retention capacity was also higher in the treatment group (7.1) than in the control group (4.8), suggesting better moisture conservation and reduced vulnerability to drought conditions.

The agricultural biodiversity index showed one of the largest differences, with the treatment group scoring 8.2 compared to 4.4 in the control group. This aligned with earlier findings on increased crop diversification and indicated a more robust and resilient farming system. Similarly, the market diversification score was higher in the treatment group (6.4) than in the control group (3.9), suggesting that households had access to a wider range of income sources and markets, thereby reducing economic risk. Climate adaptation capacity was significantly stronger in the treatment group, with a score of 7.3 compared to 4.1 in the control group. This implied that farmers in the treatment group were better equipped to cope with climate variability and shocks. Overall, the consistent positive differences across all sub-indicators demonstrated that the intervention significantly enhanced the ecological and economic resilience of participating households.

**Discussion**

The findings of this study provide robust empirical support for the hypothesis that agro-ecological practices can simultaneously improve smallholder income and agricultural sustainability in the post-conflict context of Northern Uganda. The magnitude of the income improvement (38.4%) is larger than that reported in similar agro-ecological intervention evaluations in East Africa, which typically document income gains of 20–30% over comparable timeframes (Silici, 2010; De Schutter, 2011). This above-average result may partly reflect the particularly low productivity baseline of Nwoya's degraded post-conflict soils, which provided greater room for improvement than more productive baseline contexts. The substantial reduction in input costs (41.2%) is especially significant for smallholders operating in an environment of volatile input prices and limited credit access, as it directly reduces financial risk and production vulnerability.

The soil health improvements documented in this study align with a growing body of evidence from sub-Saharan Africa demonstrating that composting, agroforestry, and legume intercropping can rapidly restore soil organic matter and microbial activity in degraded agricultural lands (Vanlauwe et al., 2014; Tittonell et al., 2012). The speed of improvement — significant changes within just two growing seasons — challenges the conventional wisdom that organic soil health improvements require a decade or more to manifest, and suggests that the combination of multiple agro-ecological practices applied simultaneously (rather than individually) may accelerate soil restoration. However, the study also documented significant barriers to agro-ecological adoption during focus group discussions. Transition period income shortfalls were cited by 62% of treatment farmers as the most significant challenge, as the first season of composting, cover cropping, and reduced synthetic fertilizer use often produces lower yields before soil health improvements take effect. This transition cost is a critical adoption barrier that program designers must address through transitional income support mechanisms. Market access for diversified produce, particularly for legumes and vegetables cultivated through intercropping, was cited as a secondary barrier by 48% of respondents, pointing to the need for integrated market development alongside agricultural practice change.

From a policy perspective, these findings make a strong case for the integration of agro-ecological approaches into Uganda's National Agriculture Policy and the Nwoya District Agricultural Investment Plan. The current policy emphasis on input subsidy programs for synthetic fertilizers and hybrid seeds is, according to this evidence, both ecologically counterproductive and economically suboptimal in the long term compared to agro-ecological alternatives. Redirecting even a portion of input subsidy budgets toward agro-ecological knowledge transfer, composting infrastructure, and transition support could generate far greater long-term returns for smallholder welfare and ecosystem integrity.

**Conclusions**

This study concludes that agro-ecological practices have highly significant positive effects on the net household income, crop diversity, soil health, and ecological resilience of smallholder farmers in Nwoya District, Northern Uganda. Treatment farmers who adopted a suite of agro-ecological practices over two agricultural seasons achieved a 38.4% increase in net agricultural income, a 41.2% reduction in input expenditure, significant improvements across all soil health indicators, and a composite ecological resilience score 72.1% higher than control farmers. These results demonstrate that agro-ecological approaches are both economically viable and ecologically restorative in the post-conflict agricultural context of Northern Uganda, providing a strong evidence base for program scaling and policy integration.

**Recommendations**

Based on these findings, the following recommendations are advanced. The Government of Uganda, through the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), should develop and fund a National Agro-Ecological Transition Program that provides targeted support to smallholder farmers during the critical first two seasons of practice adoption, including transitional income supplements and technical assistance. District Local Governments in Northern Uganda should integrate agro-ecological practices into Sub-County Agricultural Extension Services, ensuring that trained extension workers can support farmer adoption at scale. Development partners and NGOs operating in Nwoya and the broader Acholi sub-region should prioritize market development initiatives that create reliable demand and fair prices for the diversified produce generated by agro-ecological farming systems.

**Received: 08.04.2026 Accepted: 12.04.2026 Published on: 30.04.2026**

NARO should expand its applied research on agro-ecological practices adapted to the specific soil and climate conditions of Northern Uganda, with particular attention to species selection for agroforestry components and optimized composting protocols. Financial institutions and mobile money providers should collaborate with agricultural programs to develop agro-ecological savings and credit products that address smallholder financing gaps without requiring synthetic input purchases as collateral.

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**Received: 08.04.2026 Accepted: 12.04.2026 Published on: 30.04.2026**

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**Received: 08.04.2026** **Accepted: 12.04.2026** **Published on: 30.04.2026**