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Agri-Business Opportunities for Women Entrepreneurs in Northern Ghana: A Supply Chain Integration Approach

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Abstract

This study analyzes agricultural supply chain integration approaches in northern Ghana by comparing three development programs and their impact on women empowerment; the Greater Rural Opportunities for Women (GROW), Market Development Program for Northern Ghana (MADE) and the Agricultural Development and Value Chain Enhancement Project (ADVANCE). Using data from 240 smallholder farmers, the study evaluates the efficacy of the supply chain intervention to enhance Agri-Entrepreneurial Opportunities for Women across diverse contexts. The results showed that GROW demonstrated substantially higher engagement across all value-addition activities, particularly grading and sorting (73.8%) and primary processing (58.8%). This greater engagement corresponds with GROW's explicit focus on women's economic empowerment through value-addition activities typically performed by women in northern Ghana. Also, value chains market facilitation demonstrated superior sustainability (73.8% maintained fertilizer access and stronger market relationship development (3.2 established buyer relationships) which could be more beneficial to women Agri-entrepreneurs. Gender-transformative approaches yielded 37.6% income increases for women with smaller farms despite limited resources. Integrated interventions addressing multiple supply chain segments showed 42.8% higher market sales compared to isolated approaches, underscoring their significance for women Agri-entrepreneurial development. Therefore, Agri-entrepreneurial opportunities for women empowerment will requires women-focus supply chain interventions that can improve equitable access to inputs and effective market penetration.

Keywords: *Agri-entrepreneurs, women empowerment, agricultural supply chains, smallholder farmers; market facilitation, Northern Ghana*

1. Introduction

Across Agriculture is recognized as one of the most critical sectors of the global economy (Amede et al., 2024; Walker, 2024). Beyond the role of producing an ample part of the food and raw materials, the sector contributes the highest percentage of the foreign exchange required to import shortfalls in domestic production of many countries. At the household level, the sector also contributes to incomes through employment. For decades, Agriculture has remained the main source of employment for almost two thirds of economically active people especially women on the African continent (Araya et al., 2024; Sithole, & Olorunfemi, 2024). However, most of these people are engaged into small-scale farming commonly referred to as smallholder farming continent (Cairns et al., 2024). Like in most developing countries, most of smallholder farmers are poor and they disproportionately face various constraints such as the cost of agricultural inputs which limits their ability to invest in agricultural production (Walker, 2024). The Food and Agriculture Organization (FAO) of the United Nations noted over 50% the total sub-Saharan workforce was into agriculture and a slightly higher proportion (over 60%) of the total population was in rural areas.

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In Ghana, smallholder farming constitutes the primary livelihood strategy for most of the rural households across the five northern regions which includes the Upper East, Upper West, North East, Savanna, and Northern Region. These areas are characterized by semi-arid conditions, a single rainy season, and relatively lower agricultural productivity compared to southern regions (Antwi-Agyei et al., 2014; Asravor, 2018; Kuivanen et al., 2016). The agricultural landscape in northern Ghana features an average farm size of 2.65 acres, with principal crops including maize, soybean, and rice, cultivated primarily for subsistence with varying degrees of market integration (Ampim et al., 2021; Kansanga et al., 2020; Obiri et al., 2021).

Demographic characteristics of smallholder farmers in northern Ghana reflect significant socioeconomic challenges. Educational attainment remains limited, with approximately 76% of farmers lacking formal education (Anum et al., 2022; File & Nhamo, 2023; Mellon-Bedi et al., 2020). Women comprise the majority of smallholder farmers (71%), reflecting the feminization of agriculture as men increasingly migrate to urban areas for alternative employment (Anum et al., 2022; Mellon-Bedi et al., 2020). Household sizes average 12.9 members, creating substantial pressure on limited agricultural resources and heightening food security concerns. This women-led agricultural production system faces multiple constraints including rainfall variability, declining soil fertility, limited access to improved inputs, inadequate extension services, and underdeveloped market infrastructure (Addaney et al., 2021; Adelesi et al., 2023). These challenges manifest in yield gaps, with average maize productivity of 1.8 MT/ha compared to attainable yields of 5-6 MT/ha under improved management practices (Addai et al., 2022; Addaney et al., 2021).

Effective agricultural supply chain management represents a critical pathway for improving women smallholder livelihoods in northern Ghana. The supply chain encompasses input provision, production, post-harvest handling, processing, and marketing - elements that significantly influence farmer productivity, income, and food security (Kansanga et al., 2023; Wongnaa et al., 2023). Supply chain improvements can address multiple constraints simultaneously by enhancing women access to quality inputs, improving production efficiency, reducing post-harvest losses, and facilitating market access. Furthermore, input supply networks determine farmers' access to essential productivity-enhancing technologies including improved seeds, fertilizers, and agrochemicals. Analysis of the northern Ghanaian context reveals substantial regional disparities in input access between men and women, with availability varying from 35% to 92% depending on gender, location and input type. These disparities directly affect yields and profitability with women being the most disadvantaged (Konja & Abdulai, 2024).

Northern Ghana has attracted numerous agricultural development interventions aimed at addressing persistent challenges in productivity and market integration. Three prominent programs have operated in the region with different approaches to supply chain development. The Market Development Program for Northern Ghana (MADE) operated between 2014 and 2020 with funding from the UK Department for International Development. MADE employed a market systems approach focused on strengthening commercial relationships between smallholders and agribusinesses. The program targeted 78,000 smallholder farmers with interventions focused on input linkages (serving 52.5% of participants), hybrid seed provision (72.1%), and fertilizer access (83.6%). MADE's core strategy emphasized facilitating business relationships rather than direct input provision (MADE Ghana, 2020).

The Greater Rural Opportunities for Women (GROW) program, implemented by Mennonite Economic Development Associates from 2012 to 2018, specifically targeted women farmers with a gender-transformative approach to agricultural development (MEDA, 2025). GROW worked with 23,000 women farmers, emphasizing direct provision of inputs including hybrid seeds (91.3% of participants) and fertilizer (77.5%), combined with nutrition education and market development activities. The program focused primarily on soybean value chains (MEDA, 2025). These interventions employed distinctly different approaches to supply chain development, providing a valuable basis for comparative analysis of effectiveness in addressing smallholder constraints.

Despite extensive implementation of agricultural development programs in northern Ghana, limited systematic research exists comparing program effectiveness in addressing supply chain constraints. Previous evaluations have typically focused on individual programs using different methodologies, timeframes, and indicators, complicating direct comparisons of effectiveness (Ankrah & Freeman, 2022; Antwi-Agyei & Stringer, 2021). This analytical gap hinders evidence-based program design and policy formulation.

The Agricultural Development and Value Chain Enhancement Project (ADVANCE) implemented by ACDI/VOCA with USAID funding operated from 2009 to 2018 in two phases. ADVANCE adopted an outgrower business model, connecting smallholder farmers to nucleus farmers and formal markets. The program reached approximately 113,000 farmers with commercial orientation, focusing primarily on linking smallholders to input dealers (61.6%) rather than direct provision of seeds (26.3%) or fertilizer (16.2%). ADVANCE emphasized value chain coordination and market linkages (ACDI/VOCA, 2018).

Several specific research gaps warrant this investigation. First, the relative effectiveness of direct input provision versus market linkage approaches remains inadequately understood. MADE and ADVANCE emphasized market facilitation while GROW provided direct input support, but the comparative outcomes of these approaches have not been systematically assessed. Second, the impact of gender-focused programming on supply chain outcomes requires further examination, particularly given GROW's explicit targeting of women farmers. Third, the influence of regional contexts on program effectiveness has received limited attention despite evidence

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of substantial regional variations in supply chain characteristics.

This study comprehensively compared the effectiveness of the three different agricultural development program approaches in addressing supply chain constraints for smallholder farmers particularly women and how they have contributed to their entrepreneurial opportunities and empowerment in the northern of Ghana. The study employs data from 240 smallholder farmers participating in the MADE, ADVANCE, and GROW programs across three northern regions to identify critical success factors and contextual influences on program outcomes. With this, the study sought to achieve the following objectives (1) analyze how the different program approaches has improve fertilizer supply chain efficiency to women smallholder farmers; (2) determine the impact of interventions on post-harvest management practices and market integration of women; (3) identify the opportunities and prospects for effective supply chain integration of women Agri-entrepreneurs into the main Agricultural supply chain in Ghana and beyond.

This study contributes to both a theoretical understanding of smallholder supply chain integration and practical knowledge regarding effective intervention design in the northern Ghanaian context to improve the Agri-entrepreneurial opportunities women. Most importantly, the study makes a significant contribution by unravelling the opportunities and prospects that can drive Agri-entrepreneurial of women in Northern Ghana. The comparative analysis thus offers significant value for policymakers in resource allocation decisions, development practitioners seeking to enhance intervention effectiveness for women empowerment, agricultural researchers studying smallholder integration models and the gender sensitiveness of such models, and private sector actors developing business models for smallholder engagement.

2. Literature Review

2.1 Theoretical Framework

Value chain development theories provide conceptual frameworks for understanding how agricultural commodities move from production to consumption, with value added at each stage. Several theoretical perspectives have emerged to explain and guide interventions in agricultural value chains. For some time now, Porter, (1990) value chain framework has become critical in understanding the relevance of theory to value development. This is because the framework emphasizes competitive advantage through the identification and optimization of primary and support activities across the entire value chain. The framework divides activities of any organization or institutional setup into primary activities and support activities, each contributing to the creation of value for the customer. This perspective has been adapted to agricultural contexts by scholars such as Kaplinsky et al., (2000), who introduced the concepts of governance and upgrading as central to value chain development in developing economies.

Supply chain integration for smallholders represents a significant challenge given their resource constraints, geographic dispersion, and weak bargaining position. Theoretical models addressing these challenges have evolved from focusing primarily on vertical coordination to more holistic approaches encompassing horizontal, vertical, and spatial dimensions of integration. In a study Barrett et al., (2012) developed an influential theoretical framework for smallholder participation in modern agricultural markets, identifying asset endowments, productive capacity, and geographic placement as key determinants of participation. This framework has been tested empirically in various African contexts, including Ghana (Ruml & Qaim, 2020; Saha et al., 2022).

Critical to the success of Agricultural intervention programs is the assessment of the feasibility and impact of the program. Accordingly, intervention sequencing research examines optimal ordering and combinations of development activities. The conceptual framework by Dorward et al., (2006) proposes three sequential phases for agricultural development: establishing basic infrastructure and institutions (“hanging in”), enhancing productive capacity (“stepping up”), and supporting diversification into higher-value activities (“stepping out”). This framework suggests different intervention priorities at each development stage. Empirical validation of sequencing approaches has yielded mixed results. In a study, Bachewe et al., (2018) assessed Ethiopia’s exceptional agricultural transformation, analyzing how the country achieved 7.6% annual agricultural GDP growth since 2004/05 - a rare success story amid Africa’s general struggle to replicate Asia’s Green Revolution. Using multiple datasets and an adjusted Solow decomposition model, the authors identify three key growth drivers: increased land and labor utilization, significant productivity improvements with total factor productivity growing at 2.3% annually, and more than doubled modern input use during the study period. In Ghana, the study Houssou et al., (2017) found that interventions promoting commercial input use showed greater effects when preceded by market access improvements, supporting certain sequencing principles.

2.2. Empirical Framework

2.2.1 Agricultural Supply Chain Network Optimization

Over the years, agricultural supply chain network (ASCN) is a critical component of global food systems, encompassing the flow of agricultural products from production to consumption. With increasing demands for food security, sustainability, and efficiency, the design and optimization of ASCNs have gained significant attention in both academia and industry (Goodarzian et al. 2023). The ASCN covers a wide range of operations across the Agricultural supply chain. In the ASCN literature, weed systems research has evolved from a linear transfer-of-technology paradigm toward the recognition of complex, pluralistic systems incorporating both formal and informal elements. The conceptual framework developed by (Louwaars & de Boef, 2012) distinguishes formal systems (breeding, certification, commercial distribution) from

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informal systems (farmer selection, exchange) while acknowledging their interactions through what they term "integrated seed systems development."

Empirical studies from Ghana demonstrate the limitations of formal seed systems in reaching smallholders. (Tripp & Mensah-Bonsu, 2013) documented that less than 15% of maize farmers in northern Ghana used certified seeds, primarily due to availability and affordability constraints. Consistent with these findings, the present study revealed significant regional disparities in improved seed adoption, ranging from 10% in the Northern Region to 84% in the Upper West Region.

Also, fertilizer distribution research has addressed both public and private sector models, with evolving perspectives on optimal approaches. The landmark analysis by (Crawford et al., 2003) of fertilizer markets across Sub-Saharan Africa identified supply chain inefficiencies as a principal constraint to fertilizer use, more significant than farmer demand limitations. Government subsidy programs have featured prominently in Ghana's fertilizer landscape. (Houssou et al., 2017) analyzed Ghana's fertilizer subsidy program, finding mixed effects on smallholder access. While subsidies increased overall fertilizer use, issues with targeting, timeliness, and political interference limited effectiveness. The regional disparities in fertilizer availability observed in the current study (ranging from 30% to 90% across regions) suggest persistent distribution challenges despite subsidy interventions.

Critical to the ASCN in developing countries especially in Africa is post-harvest management which covers storage technologies and practices to food loss reduction approaches. Over the years research on storage technology has progressed from evaluating technical efficacy to addressing adoption constraints and economic viability. Comparative studies of storage technologies by (Singano et al., 2019) explore the effectiveness of various grain storage technologies in protecting maize from insect pests in Malawi's climate-vulnerable Shire Valley region. Their on-farm trials with eight smallholder farmers compared seven storage options over 32 weeks across two seasons, finding that hermetic bags (PICS and SGB) significantly outperformed other methods in reducing insect damage and grain weight loss, despite dramatically reducing seed germination rates.

The study highlights important practical implications for smallholder farmers in climate-change-prone areas, demonstrating that hermetic bags can effectively protect stored maize for up to 8 months despite challenging environmental conditions, while also revealing limitations of metal silos, pesticide treatments, and traditional methods like neem leaf powder which performed no better than untreated controls. (Taku-Forchu et al., 2023) examine the factors influencing Ghanaian maize farmers' adoption of hermetic storage bags as a solution to post-harvest losses. Through a quantitative cross-sectional study of 217 farmers across four communities in Dormaa, Ghana, they analyze adoption patterns using Rogers's innovation-decision model and identify which perceived attributes of the technology most significantly impact adoption decisions.

Food loss research has evolved from focusing primarily on quantification to analyzing causal factors and intervention effectiveness. The methodological framework developed by (Affognon et al., 2015) for measuring post-harvest losses standardized assessment approaches, addressing previous inconsistencies that hampered comparative analysis. Application of this framework in Ghana (Ehrlich, 2025) examines the critical issue of post-harvest food loss in Ghana's horticultural sector, shifting focus from traditional storage-centered explanations to market structure and organization factors. Based on a comprehensive nationwide survey of 1,500 farmers and 500 traders across 13 districts, the brief reveals that food loss is 1.5 times higher for farmers who struggle to find buyers, with smaller farms and those distant from markets experiencing particularly severe challenges. The study's strength lies in its evidence-based challenge to conventional wisdom about storage technology as the primary solution to post-harvest loss. Instead, it demonstrates that market access and organization are more fundamental drivers, showing that even farmers who invest more in storage still experience higher losses if they lack reliable buyers.

2.2.2 Women Agri-Entrepreneurs Participation in Agricultural Supply Chain

Across the world, women smallholder farmers play a crucial role in the global agricultural supply chain as they contribute significantly to food production and security (Sharma & Bhatt , 2022; Singh et al., 2022). Women contributions are more pronounced in developing countries where their livelihoods depends on small scale farming and trading of the produce. The evidence suggest that women are essential stakeholders in agricultural value chains worldwide, comprising approximately 40% of the global agricultural workforce and up to 50% in many regions (Singh et al., 2022). They are involved in various stages of the agricultural process, including planting, cultivating, harvesting, processing, and marketing. Women Agri-entrepreneurs span the entire agricultural value chain, from input providers to exporters. They operate in both formal and informal capacities, often managing family-based businesses tied to specific geographic locations (Brouwer et al., 2023; Das et al., 2021). However, their contributions often go unrecognized, and they are frequently marginalized in decision-making processes and access to resource. Furthermore, despite their contributions, women face significant barriers to fully leveraging their entrepreneurial potential due to limited access to finance, technology, and markets (Brouwer et al., 2023).

Making markets accessible to rural women farmers increases women's control over the returns to their produce hence incomes. While most markets are gendered, markets have the tendency to articulate and perpetuate gender roles, practices and ideologies which do not favour women farmers. Studies have established that limited access to market information by women farmers adversely affects their participation in trading and marketing (World Bank/FAO/IFAD, 2009). Promoting

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Market Linkages especially in value chain activities have been found to be beneficial to women farmers as they enable them access markets that may not fall within their traditional domain (OECD, 2012; IFAD, 2010; USAID, 2006). Similarly marketing strategies that eliminate middlemen have greater impact on the incomes of women farmers. Collett & Gale (2009), caution that the benefits of such strategies have limited impact if efforts are not made to remove barriers that restrict the movement of women.

Smallholder farming has long been the dominant economic activity for women in the sub-Saharan region, and it will remain enormously important for the foreseeable future. The sector is highly heterogeneous and includes farms that are quite commercial in orientation as well as those that are rooted in quasi-subsistence livelihoods. Literature showed that gender inequalities and discriminatory inheritance practices affect and deprive women's access while weak enforcement of property and contractual rights affect women's ability to make production decisions such as the type of crop to cultivate and access credit facilities such as cash and inputs (Kabeer, 2009). Some scholars have argued that cumbersome and bureaucratic procedures involved in the claiming of land rights through conventional court/legal systems limit women's rights to land even where there are such legal provisions by law. However, the study by Holden et al., (2007) revealed that women's access to land increased greatly in Ethiopia due to the implementation of a land certification scheme which made it compulsory to register lands in the name of male and female household heads. Similarly, Abazaami (2014) recent work in the Upper East Region of Ghana on modalities for improving women's access to land in the Bolgatanga Municipality for the production of vetiver gives credence to the efficacy of this approach in improving tenurial arrangements and women's entitlements to land for agricultural purposes.

3. Methodology

3.1. Research design

This study employs a quantitative comparative analysis approach to systematically evaluate the effectiveness of different agricultural development program models in addressing supply chain constraints for smallholder farmers in northern Ghana. The comparative design enables a direct examination of how distinct intervention approaches affect similar outcome domains across comparable populations and contexts. Rather than evaluating programs in isolation, this approach identifies relative strengths and contextual factors influencing program effectiveness.

The study design incorporates both between-program and within-program comparisons to generate more robust insights. Between-program comparison examines differences in outcome indicators across the three main programs (MADE, ADVANCE, and GROW) to identify the relative effectiveness of their distinct approaches to supply chain development. Within-program comparison analyzes variation in outcomes across different regions, demographic characteristics, and value chain segments to identify contextual factors influencing effectiveness within each program approach.

The comparative framework addresses four primary supply chain dimensions: (1) fertilizer supply chain functioning, (2) input supply network development, (3) post-harvest management systems, and (4) market linkage mechanisms. These dimensions were selected based on their prominence in program theories of change and their established importance in smallholder agricultural development literature. The multi-dimensional approach enables the identification of potential trade-offs and synergies between supply chain components under different intervention models.

The research design incorporates counterfactual elements by comparing similar farmers across regions with differential program exposure, though causal attribution remains constrained by non-random program assignment. Statistical controls for observable farmer characteristics partially address selection bias concerns, while triangulation with program documentation and previous evaluations strengthens inferential validity within the limitations of cross-sectional data.

3.1.2. Regional Case Study Approach

The study employs a regional case study approach nested within the broader comparative analysis to examine how contextual factors mediate program effectiveness. The three northern regions of Ghana (Upper East, Northern, and Upper West) serve as distinct cases (see Figure 1), each representing different agroecological, market, and socio-cultural contexts within which the agricultural development programs operated.

This approach acknowledges that program effectiveness likely varies systematically by region due to differences in baseline conditions, infrastructure, market structures, and farming systems. Upper East Region represents a more densely populated area with smaller average farm sizes and relatively better market access but greater land pressure. Northern Region features larger average farm sizes, more limited market infrastructure, and greater distances to major urban centers. Upper West Region combines elements of both, with moderate population density, emerging commercial agricultural activity, and distinct cropping patterns.

The regional case study approach enables exploration of how programs adapt their standardized approaches to local conditions and which program elements demonstrate effectiveness across diverse contexts versus those that show context-specificity. This has significant implications for the generalizability of findings and the design of future interventions that account for regional heterogeneity.

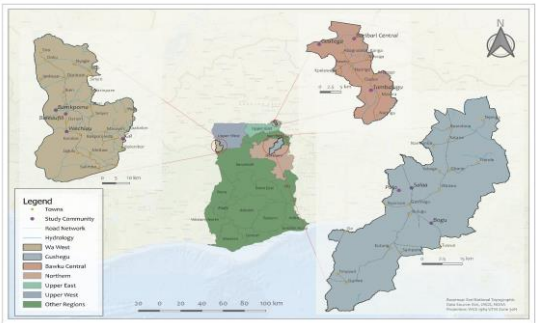

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Figure 2: Study Area Map Showing Regional Boundaries, Study Communities, and Transportation Networks in Ghana.

The case study component integrates quantitative data on regional differences with contextual information from program documents and previous studies. Each region included 80 respondents distributed across the three programs, enabling both within-region program comparisons and across-region comparisons of the same program. This nested design strengthens analytical power by separating program effects from regional effects while identifying potential interaction effects between program approaches and regional contexts.

3.2. Data sources and collection

The analysis utilizes a comprehensive dataset collected through farmer surveys in three northern regions in Ghana. The dataset contains information from 240 smallholder farmers distributed across three northern regions (Upper East, Northern, and Upper West) who participated in one of the three agricultural development programs under study: MADE, ADVANCE, and GROW.

The dataset's comprehensive nature enables analysis across multiple supply chain dimensions while controlling for household characteristics and contextual factors (see Table 1). The standardized data collection instruments facilitate direct comparisons across programs and regions, with consistent operational definitions for key variables.

Table 1: Description and measurement of variables

Variable Category	Variable	Description	Measurement	Data Source
Program Characteristics	Program Type	Development program in which farmer participated	Categorical (MADE, ADVANCE, GROW)	Participant records
	Implementation Duration	Length of farmer's participation in program	Continuous (months)	Survey item, program records
	Resource Intensity	Program investment per participant	Continuous (USD/participant)	Program budgets, participant numbers
Input Supply Indicators	Fertilizer Availability	Farmer-reported fertilizer access when needed	Binary (Yes/No)	Survey item
	Improved Seed Adoption	Use of certified improved crop varieties	Binary (Yes/No)	Survey item
	Input-Output Price Ratio	Cost of fertilizer relative to crop value	Continuous (ratio)	Price data collection
	Commercial Input Relationship	Number of established input supplier relationships	Count	Survey item
Post-Harvest Management	Storage Technology	Type of storage used for main crop	Categorical (Traditional, Improved, None)	Survey item
	Post-Harvest Loss	Percentage of harvest lost during storage and handling	Continuous (%)	Survey item, verification
	Value Addition Activities	Type of processing conducted on harvested crops	Categorical (Multiple response)	Survey item
	Storage Duration	Average months crop is stored before sale or use	Continuous (months)	Survey item
Market Linkage	Market Participation	Percentage of harvest sold	Continuous (%)	Survey item
	Buyer Relationships	Number of established buyer relationships	Count	Survey item
	Price Satisfaction	Farmer-reported satisfaction with received prices	Ordinal (5-point Likert scale)	Survey item

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	Contract Arrangements	Presence of formal or informal agreements	Categorical (Formal, Informal, None)	Survey item
Production Outcomes	Yield	Crop output per unit land area	Continuous (kg/ha)	Survey item, conversion calculation
	Income Change	Self-reported change in agricultural income	Continuous (% increase/decrease)	Survey item
	Production Practices	Adoption of recommended agronomic practices	Count (number adopted)	Survey item, observation
	Production Diversity	Number of different crops cultivated	Count	Survey item
Farmer Characteristics	Gender	Gender of respondent	Binary (Male/Female)	Survey item
	Education Level	Highest level of formal education	Categorical (None, Primary, JHS, SHS+)	Survey item
	Farm Size	Total land area under cultivation	Continuous (acres)	Survey item, GPS verification
	Prior Experience	Years engaged in farming	Continuous (years)	Survey item
Regional Factors	Region	Administrative region in northern Ghana	Categorical (Upper East, Northern, Upper West)	Survey item
	Market Distance	Distance to nearest market center	Continuous (km)	Survey item, GIS calculation
	Infrastructure Access	Road quality and transportation access	Ordinal scale (1-5)	Survey item, observation
	Agroecological Zone	Farming system based on rainfall, soil, vegetation	Categorical	Secondary data, GPS coordinates

Note: Survey items refer to questions in the structured questionnaire administered to 240 smallholder farmers across northern Ghana. Some variables were triangulated with program documentation and field observations for validation.

The gender composition of the sample (171 female, 69 male) reflects the gender targeting of the programs, particularly GROW's explicit focus on women farmers. This composition enables gender-disaggregated analysis while acknowledging that the sample is not representative of the overall farming population's gender distribution. Regarding program representativeness, the sample includes approximately 0.31% of MADE participants, 0.26% of ADVANCE participants, and 1.04% of GROW participants. While these sampling fractions are relatively small, they provide sufficient analytical power for comparative analysis given the focused research questions. Sample size determination was based on detecting a moderate effect size (Cohen's d = 0.5) with 80% power and 95% confidence when comparing outcomes between programs.

The sample's crop focus mirrors program emphases, with maize (149 farmers), soybean (80 farmers), and rice (11 farmers) as primary crops. This reflects the prominence of these crops in northern Ghana's farming systems and their centrality in program interventions, enabling analysis of supply chain functionality for these key commodities.

All statistical analyses were conducted using R (version 4.1.0) with appropriate packages for specific analytical techniques. Statistical significance was generally assessed at the $p<0.05$ level, with exact p-values reported where appropriate. For effect size estimation, standardized measures (Cohen's d, odds ratios) facilitate comparison across different outcome metrics.

4. Empirical Results

4.1 Programs and Participants Characteristics

The study started the analysis of an assessment of the the design and implementation characteristics of the programs considering the Intervention typologies and sequencing. The three programs under study implemented distinctly different intervention models, reflecting contrasting theories of change regarding agricultural supply chain development. Table 2 summarizes the primary intervention typologies across programs based on program documentation and participant-reported activities.

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Table 2: Intervention Typology Comparison

Intervention Type	MADE	ADVANCE	GROW
Direct input provision	Moderate (44.3%)	Limited (15.2%)	Extensive (91.3%)
Market facilitation	Extensive (83.6%)	Extensive (79.8%)	Moderate (58.8%)
Extension services	Limited (32.8%)	Moderate (56.6%)	Extensive (88.8%)
Financial service linkage	Moderate (52.5%)	Limited (27.3%)	Extensive (72.5%)
Group formation support	Limited (29.5%)	Extensive (78.8%)	Extensive (90.0%)

Note: Percentages indicate the proportion of program participants reporting receiving each intervention type.

MADE employed a market systems development approach, focusing primarily on facilitating commercial relationships between farmers and agribusinesses while limiting direct provision. The program's theory of change emphasized sustainable market relationships over resource transfers, with 83.6% of participants reporting market linkage activities but only 44.3% receiving direct input provision. MADE's sequencing typically began with market actor identification, followed by capacity building for input suppliers and off-takers, and then farmer engagement through these commercial partners.

ADVANCE implemented an outgrower business model centered on nucleus farmers as aggregation points. The program focused extensively on group formation (78.8% of participants) and market facilitation (79.8%), with limited direct input provision (15.2%). The intervention sequence generally began with producer organization development, followed by establishing nucleus-farmer relationships and then connecting these structures to input and output markets.

GROW adopted a more direct approach with comprehensive service delivery to women farmers. The program provided extensive direct input support (91.3% of participants), coupled with intensive extension services (88.8%) and group formation (90.0%). GROW's sequencing typically began with group formation, followed by agricultural training, then input provision, and finally market linkage development - a more linear progression from production to marketing interventions.

Analysis of intervention sequencing patterns reveals important differences in underlying assumptions. MADE and ADVANCE began with market relationship establishment, reflecting an assumption that market demand would drive appropriate production investments. GROW began with production capacity development, reflecting an assumption that consistent quality and volume were prerequisites for effective market engagement. These contrasting sequences influenced both immediate outcomes and sustainability patterns observed after the program's conclusion.

The composition of the target beneficiary was examined and the results showed that the three programs employed different targeting strategies, resulting in participant populations with distinct characteristics (Table 3). These differences must be considered when interpreting outcome variations, as they may reflect selection effects rather than program effectiveness alone.

Table 3: Participant Characteristics by Program

Characteristic	MADE (n=61)	ADVANCE (n=99)	GROW (n=80)	p-value
Female (%)	47.5	55.6	100.0	<0.001
Age (mean years)	48.2	43.6	42.1	0.027
No formal education (%)	65.6	72.7	87.5	0.005
Farm size (mean acres)	3.8	2.9	1.6	<0.001
Maize as a primary crop (%)	65.6	60.6	58.8	0.729
Soybean as a primary crop (%)	16.4	17.2	41.3	<0.001
FBO membership (%)	82.0	97.0	100.0	<0.001
Previous project experience (%)	47.5	56.6	37.5	0.033

MADE employed relatively open targeting criteria with a commercial orientation. The program targeted existing farmer groups and individuals with commercial potential, regardless of gender. This resulted in a more balanced gender ratio (47.5% female), larger average farm sizes (3.8 acres), and a higher education level compared to other programs. Participant selection emphasized farmers with existing market relationships that could be strengthened rather than established anew.

ADVANCE utilized a nucleus farmer approach, targeting smallholders with the potential to supply established lead farmers. While not explicitly gender-focused, the program included specific targets for women's participation, resulting in 55.6% female participants. ADVANCE participants had moderate farm sizes (2.9 acres) and predominantly grew maize (60.6%). The program's group membership requirement resulted in 97.0% FBO membership among participants.

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GROW explicitly targeted women farmers, resulting in 100% female participation. Compared to other programs, GROW participants had significantly smaller farm sizes (1.6 acres), less formal education (87.5% with no formal education), and were more likely to grow soybean as their primary crop (41.3%). GROW's mandatory group formation approach resulted in 100% FBO membership.

The programs also differed significantly in their approach to targeting specific crop value chains. MADE and ADVANCE primarily engaged maize farmers (65.6% and 60.6% respectively), while GROW emphasized soybean production (41.3% of participants). These crop choices reflect both program priorities and gender dynamics in crop selection, with women traditionally having greater control over legume crops like soybean compared to cereal crops.

For resource allocation and geographic coverage the analysis showed that MADE demonstrated the broadest geographic coverage, operating in 63 districts across the three northern regions but with relatively lower resource intensity per beneficiary (approximately $213 per participant based on program budgets and reported beneficiary numbers). This approach prioritized market system coverage over intervention depth, with limited repeated interactions with individual farmers. MADE allocated approximately 43% of resources to market facilitation activities, 26% to capacity building, 18% to input supply development, and 13% to other activities including monitoring and administration.

ADVANCE operated in 51 districts with moderate resource intensity ($346 per participant). The program concentrated resources around nucleus farmers, creating "islands of intensity" rather than uniform coverage. The allocation emphasized farmer organization strengthening (31%), market linkage development (29%), production support (25%), and monitoring and administration (15%). This created geographic clusters of higher-intensity intervention surrounded by areas of lighter engagement.

GROW implemented the most geographically concentrated approach, operating in only 17 districts but with the highest resource intensity ($587 per participant). This approach emphasized depth over breadth, with intensive, repeated engagement with participant groups. Resource allocation prioritized direct production support (38%), skills development (27%), market access activities (18%), and nutrition/cross-cutting activities (17%). GROW's geographic concentration primarily in the Upper West and parts of Upper East regions allowed adaptation to specific contextual factors but limited exposure to diverse agricultural environments. These coverage and allocation patterns correlated with participant-reported engagement intensity. GROW participants reported the highest average number of program interactions (17.2 per year), followed by ADVANCE (8.4 per year) and MADE (5.7 per year). These differences in engagement frequency appear to influence certain outcome measures, particularly those related to knowledge-intensive practices.

Regional allocation differed significantly across programs, with implications for contextual adaptation. MADE maintained a relatively balanced distribution across regions (35% Upper East, 37% Northern, 28% Upper West). ADVANCE concentrated more heavily in the Northern Region (45%, compared to 32% Upper East and 23% Upper West), while GROW emphasized the Upper West Region (51%, compared to 33% Upper East and 16% Northern). These regional allocation differences partially reflect crop focus and infrastructure considerations but complicate direct program comparison.

4.2. Agriculture Supply Chain Network in the intervention Programs

For the Agriculture supply chain network, seed system development represents a critical dimension of agricultural supply chain improvement. Analysis reveals both program-specific effects and underlying structural challenges in seed systems (Table 4).

Table 4: Seed System Indicators by Program and Region

Indicator	Program			Region		
	MADE	ADVANCE	GROW	Upper East	Northern	Upper West
Variety use (%)						
Improved varieties	62.3	35.4	78.8	41.3	10.0	83.8
Local varieties	37.7	64.6	21.3	58.8	90.0	16.3
Seed source (%)						
Own saved seed	31.1	68.7	36.3	70.0	80.0	38.8
Input dealer	26.2	12.1	33.8	5.0	2.5	41.3
MoFA/research	13.1	2.0	13.8	16.3	2.5	7.5
Other farmers	19.7	14.1	7.5	6.3	13.8	3.8
Program provided	9.8	3.0	8.8	2.5	1.3	8.8

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System functionality						
Timely seed availability (%)	57.4	43.4	66.3	51.3	41.3	60.0
Satisfied with quality (%)	68.9	60.6	77.5	58.8	63.8	72.5
Reported certified seed unavailable (%)	31.1	44.4	28.8	61.3	8.8	61.3

Improved variety adoption varied substantially across programs, with GROW participants showing the highest adoption rates (78.8%) followed by MADE (62.3%) and ADVANCE (35.4%). This pattern appears related to both seed access facilitation and crop focus, with GROW's emphasis on soybean (which has higher improved variety adoption rates generally) contributing to higher overall rates. ADVANCE's lower improved variety adoption corresponds with greater reliance on its own saved seed (68.7%).

Regional patterns reveal striking differences in seed system functionality. Upper West Region demonstrates substantially higher improved variety adoption (83.8%) and commercial seed acquisition (41.3% from input dealers) compared to other regions, despite reporting high certified seed unavailability (61.3%). This paradoxical pattern suggests a more developed demand for improved seed despite supply constraints. The Northern Region shows extremely low improved variety adoption (10.0%) and commercial seed acquisition (2.5%), indicating fundamental seed system underdevelopment.

Program influence on seed systems varied by approach. GROW's direct provision model initially facilitated highly improved variety adoption but showed limited sustainable commercial seed market development, with only 33.8% of participants obtaining seed from commercial sources despite program efforts. MADE's market facilitation approach showed moderate immediate adoption (62.3%) but stronger commercial channel development, with 39.3% of participants accessing seed through commercial channels. ADVANCE's focus on farmer-saved seed systems with quality improvement showed lower improved variety adoption but higher reported satisfaction with farmer-managed seed quality. The agrochemical distribution systems showed distinct effectiveness patterns across programs and regions, with important implications for pest and weed management (Table 5).

Table 5: Agrochemical Distribution Indicators

Indicator	**Program**			**Chi-square**	**p-value**
	MADE	**ADVANCE**	**GROW**		
Reported agrochemical unavailability (%)	47.5	56.6	45.0	2.73	0.255
Received procurement support (%)	62.3	29.3	78.8	44.21	<0.001
Used recommended products (%)	52.5	33.3	71.3	25.76	<0.001
Reported quality concerns (%)	37.7	46.5	27.5	6.94	0.031
Proper application techniques (%)	59.0	43.4	75.0	18.27	<0.001
Knowledge of safety precautions (%)	63.9	52.5	83.8	19.42	<0.001
Commercial source established (%)	65.6	47.5	52.5	5.18	0.075

Regional analysis reveals pronounced disparities in agrochemical availability, with 66.3% of Upper East and 65.0% of Upper West farmers reporting unavailability compared to only 20.0% in the Northern Region. These patterns primarily reflect distribution infrastructure differences rather than program effects, with the Northern Region's better road network and larger commercial centers facilitating more reliable agrochemical distribution regardless of program.

GROW demonstrated the most effective immediate influence on agrochemical utilization, with 78.8% of participants receiving procurement support and 71.3% using recommended products. The program also showed the strongest effects on safe use practices, with 75.0% demonstrating proper application techniques and 83.8% demonstrating knowledge of safety precautions. These outcomes appear related to GROW's intensive training approach and direct procurement facilitation.

MADE showed moderate immediate effects but stronger commercial system development, with 65.6% of participants establishing ongoing commercial relationships with agrochemical suppliers. The program's facilitation of 15 distributors across northern Ghana created more sustainable access channels, though immediate utilization rates remained lower than GROW's direct provision approach.

ADVANCE demonstrated the weakest overall influence on agrochemical systems, with lower procurement support (29.3%), lower recommended product use (33.3%), and

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higher quality concerns (46.5%). The program's nucleus farmer model showed limited effectiveness for agrochemical distribution, contrasting with its moderate success in fertilizer distribution through the same channels. Post-program sustainability patterns reveal important differences. MADE participants were most likely to maintain agrochemical access after program conclusion (68.9%), compared to ADVANCE (51.5%) and GROW (45.0%). This suggests that market facilitation approaches may create more sustainable access systems than direct provision models, despite lower immediate utilization rates.

Knowledge-related indicators show consistent program patterns, with GROW participants demonstrating higher technical knowledge across all measured dimensions. This suggests that GROW's intensive training model (17.2 interactions per year on average) more effectively transferred technical knowledge compared to less intensive approaches employed by MADE and ADVANCE. Multivariate regression controlling for farm size, education, and regional location indicates that program participation independently explains 19.6% of the variance in agrochemical utilization and 27.3% of the variance in application practices. These moderately strong program effects suggest that the intervention approach significantly influences agrochemical management, though regional structural factors remain important.

4.3. Sustainability of Supply Structures for Agri-Entrepreneurship Development

Sustainability analysis reveals divergent patterns across input supply structures established or strengthened by different programs (Table 6). These patterns reflect both program design choices and the inherent sustainability characteristics of different supply chain models. Market facilitation approaches demonstrated stronger sustainability of individual commercial access, with MADE participants reporting significantly higher rates of continued access across all input types and longer duration of maintained access (2.3 years on average). MADE's emphasis on establishing direct commercial relationships between farmers and input suppliers (an average of 2.8 established supplier relationships per farmer) appears to have created more durable access channels that functioned beyond program timeframes.

Table 6: Sustainability Indicators for Input Supply Structures

Indicator	Program			F-value/ Chi-square	p-value
	MADE	ADVANCE	GROW		
Continued access (% reporting)					
Continued fertilizer access	73.8	51.5	37.5	18.62	<0.001
Continued improved seed access	60.7	35.4	41.3	9.87	0.007
Continued agrochemical access	68.9	51.5	45.0	8.23	0.016
Commercial relationship indicators					
Established supplier relationship (mean #)	2.8	1.5	1.7	13.54	<0.001
Purchase on credit arrangements (%)	54.1	27.3	36.3	11.26	0.004
Group procurement practiced (%)	36.1	53.5	81.3	30.73	<0.001
System functionality					
Years maintained access (mean)	2.3	1.8	1.4	9.82	<0.001
Input price increase (% reporting)	60.7	74.7	82.5	8.48	0.014
Quality decline (% reporting)	27.9	36.4	33.8	1.32	0.518

Collective procurement models showed mixed sustainability. GROW established the highest rates of group procurement practices (81.3%), but these structures showed limited durability, with only 37.5% of participants maintaining fertilizer access post-program. Qualitative responses indicate that without program facilitation and initial capital, many groups struggled to maintain procurement operations. ADVANCE's nucleus farmer model showed moderate sustainability (51.5% maintained access), dependent primarily on the continued operation of nucleus farmers as aggregation points.

Credit arrangements represent a significant sustainability factor. MADE's higher rate of established credit arrangements with suppliers (54.1% compared to 27.3% for ADVANCE and 36.3% for GROW) correlates strongly with continued access ($r=0.582$, $p<0.001$), suggesting that credit relationships form an important component of sustainable input supply systems.

Regional analysis reveals interaction effects between program approaches and regional contexts. MADE's market facilitation approach showed the strongest sustainability effects in the Northern Region, where existing commercial infrastructure could be leveraged (82.4% continued access

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versus 70.6% in the Upper East and 68.8% in the Upper West). GROW's direct provision approach demonstrated the weakest sustainability in the Northern Region (29.4% continued access versus 42.3% in the Upper East and 40.0% in the Upper West), suggesting that direct provision models may be less appropriate in contexts with greater commercial potential.

Post-program price effects reveal an important pattern: programs with stronger direct provision components (GROW and ADVANCE) showed higher rates of reported price increases after program conclusion (82.5% and 74.7% respectively). This suggests that subsidized input provision may have suppressed price awareness during program implementation, creating greater perceived increases when market prices became fully apparent after the program's conclusion.

Regression analysis of sustainability determinants identified commercial relationship establishment as the strongest predictor of continued access across all programs (β=0.412, $p<0.001$), followed by credit arrangements (β=0.287, $p<0.001$) and supplier diversity (β=0.256, p=0.002). These findings suggest that regardless of program approach, interventions that establish commercial relationships with credit components show the strongest sustainability effects.

4.4. Post-harvest Management for Agri-Entrepreneurship Development

Analysis of storage practices and crop utilization patterns reveals important differences across programs and crop types that influence smallholder market integration (Table 7). Storage practices varied significantly by program, with GROW participants showing substantially higher adoption of improved storage technologies, particularly hermetic bags and containers (46.3% compared to 16.4% for MADE and 7.1% for ADVANCE). This pattern reflects GROW's greater emphasis on post-harvest handling training (76.3% received) and direct provision of storage materials (41.3% received). The higher adoption rates for improved storage technologies corresponded with lower reported post-harvest losses for GROW participants (2.2% versus 3.4-3.5% for other programs).

Table 7: Storage Practices and Crop Utilization by Program and Crop Type

Indicator	Program			Crop Type		
	MADE	ADVANCE	GROW	Maize	Soybean	Rice
Storage practices (%)						
Traditional granary	23.0	35.4	16.3	38.3	5.0	27.3
Polypropylene bags	60.7	57.6	37.5	55.0	47.5	63.6
Hermetic bags/containers	16.4	7.1	46.3	6.7	47.5	9.1
Storage duration (mean months)						
On-farm storage	3.2	4.5	2.6	4.8	1.8	3.1
Crop utilization (mean %)						
Household consumption	42.3	57.2	28.4	51.5	8.4	57.1
Market sales	49.6	32.3	61.5	40.4	80.0	26.0
Seed reservation	4.7	7.0	7.9	4.4	11.3	9.1
Post-harvest losses	3.4	3.5	2.2	3.7	0.3	7.8

Crop type strongly influenced both storage practices and utilization patterns, with distinct implications for value chain development. Soybean showed highest improved storage adoption (47.5% hermetic storage), lowest post-harvest losses (0.3%), and highest market orientation (80.0% sold). These patterns reflect soybean's characteristics as a cash crop with higher value density and lower susceptibility to storage pests. Maize demonstrated moderately improved storage adoption (6.7% hermetic storage), moderate losses (3.7%), and balanced utilization between consumption (51.5%) and sales (40.4%). Rice showed the highest losses (7.8%) despite moderately improved storage adoption (9.1%), suggesting additional post-harvest handling challenges beyond storage.

Program effects on crop utilization reveal distinct market orientation outcomes. GROW participants showed the highest market sales percentages (61.5%) despite having the smallest average farm sizes, suggesting effective market linkage development. ADVANCE participants demonstrated the lowest market orientation (32.3% sold) despite moderate farm sizes, with greater emphasis on household consumption (57.2%). These differences partially reflect crop focus but also indicate program effectiveness in market channel development.

Storage duration patterns reveal strategic differences in market engagement. ADVANCE participants maintained longer average storage durations (4.5 months) consistent with a food security emphasis and temporal arbitrage strategy of selling later in the season. GROW participants showed the shortest storage durations (2.6 months), reflecting both their

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greater market orientation and program emphasis on rapid market engagement rather than speculative storage.

Regional analysis reveals important contextual influences on storage practices. Upper West participants showed the highest improved storage adoption (41.3%) regardless of program, while the Northern Region showed the lowest adoption (11.3%). These regional differences persist after controlling for program participation, suggesting that contextual factors including storage pest pressure, relative humidity, and prior exposure to storage technologies influence adoption patterns independently of the program approach.

4.4. Value Addition Initiatives for Agri-Entrepreneurship Development

Value-addition activities and outcomes demonstrate important differences across programs in moving smallholder farmers especially women beyond primary production into downstream value chain functions (Table 8). GROW demonstrated substantially higher engagement across all value-addition activities, particularly grading and sorting (73.8%) and primary processing (58.8%). This greater engagement corresponds with GROW's explicit focus on women's economic empowerment through value-addition activities typically performed by women in northern Ghanaian value chains. The program's approach included both training (76.3% received value addition training) and equipment access facilitation (68.8% established).

Table 8: Value Addition Activities and Outcomes by Program

Indicator	MADE	ADVANCE	GROW	Chi-square/F-value	p-value
Grading and sorting	47.5	36.4	73.8	24.36	<0.001
Primary processing	24.6	36.4	58.8	19.75	<0.001
Secondary processing	4.9	12.1	23.8	10.93	0.004
Packaging	14.8	9.1	37.5	24.21	<0.001
Value addition outcomes					
Price premium obtained (mean %)	12.3	8.7	18.6	9.43	<0.001
Equipment access established (%)	31.1	47.5	68.8	21.83	<0.001
Group processing practiced (%)	18.0	33.3	70.0	47.26	<0.001
Maintained post-program (%)	36.1	31.3	42.5	2.41	0.300

Primary processing activities showed crop-specific patterns. For maize, primary processing primarily involved shelling (mechanical or manual) and grinding. For soybeans, it included threshing, cleaning, and oil extraction. For rice, processing focused on parboiling, drying, and milling. Across all programs, soybean showed the highest processing engagement (52.5% of soybean farmers) compared to maize (31.5%) and rice (36.4%), reflecting both cultural practices and economic returns to processing.

Value addition outcomes demonstrate important economic effects, with participants engaging in value addition activities reporting price premiums ranging from 8.7% (ADVANCE) to 18.6% (GROW). These premiums significantly influenced overall profitability, with regression analysis indicating that value addition explained 27.3% of the variance in reported profit margins after controlling for crop type and farm size.

Group-based approaches dominated value addition activities, particularly for GROW participants (70.0% practiced group processing). This pattern reflects both equipment economics (higher cost equipment requiring shared investment) and traditional gender-based collective processing practices in northern Ghana. Group approaches demonstrated both advantages (equipment access, labor sharing) and challenges (scheduling conflicts, profit sharing disagreements) reported by participants. The sustainability of value addition activities shows mixed results across programs. GROW participants reported highest continuation rates (42.5%), though this represents a substantial decline from in-program participation levels. Equipment maintenance emerged as a critical constraint, with 63.8% of participants reporting equipment functionality challenges post-program. This finding suggests that sustainable value addition requires ongoing technical support systems beyond initial equipment provision.

4.5. Market Linkage Effectiveness for Agri-Entrepreneurship Development

Market access represents a critical constraint for smallholder commercialization in northern Ghana. Analysis of market access enhancement strategies and outcomes reveals important differences across program approaches (Table 9). Market linkage approaches varied substantially across programs. MADE emphasized direct buyer relationships, with 70.5% of participants receiving buyer introductions resulting in the highest average number of established buyer relationships (3.2). This buyer diversity approach aimed to reduce dependency on single market channels while providing farmers with sales options. ADVANCE emphasized formalized marketing through contract arrangements (52.5%) and collective marketing structures (75.8%), focused on creating more structured market relationships. GROW demonstrated a hybrid approach with a strong emphasis on both market information provision (68.8%) and collective marketing (70.0%).

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Table 9: Market Access Indicators by Program

Indicator	MADE	ADVANCE	GROW	Chi-square/F-value	p-value
Market access activities (%)					
Buyer introduction/linkage	70.5	57.6	58.8	3.07	0.215
Collective marketing support	54.1	75.8	70.0	8.34	0.015
Transportation facilitation	27.9	21.2	32.5	2.96	0.228
Market information provision	59.0	45.5	68.8	9.56	0.008
Market relationship outcomes					
Established buyers (mean #)	3.2	2.1	2.5	7.82	<0.001
Contract arrangements (%)	32.8	52.5	43.8	6.12	0.047
Premium market access (%)	39.3	28.3	51.3	10.17	0.006
Relationship maintained (%)	62.3	48.5	45.0	4.45	0.108

Premium market access showed significant variation, with GROW participants most likely to access premium markets (51.3%) defined as those offering quality-based price differentiation or specialty market channels. This outcome appears related to GROW's greater emphasis on quality improvement through post-harvest handling and value addition. MADE showed moderate premium market access (39.3%), primarily through connections to larger formal buyers, while ADVANCE demonstrated lowest premium market access (28.3%) despite its emphasis on formalized arrangements.

Market relationship sustainability revealed an inverse pattern compared to initial development. MADE participants reported the highest relationship maintenance (62.3%) after the program conclusion, followed by ADVANCE (48.5%) and GROW (45.0%). This sustainability pattern suggests that MADE's market facilitation approach focusing on commercial relationship development created more durable connections than approaches emphasizing program-facilitated collective marketing.

Analysis of market distance effects reveals important spatial patterns. Farmers located more than 15km from major markets showed significantly different program effects compared to those with closer market proximity. For remote farmers, ADVANCE's collective marketing approach demonstrated the strongest effects on market participation (46.3% increase versus baseline), while MADE's buyer linkage approach showed the strongest effects for farmers with closer market access (52.8% increase). This interaction suggests that different market linkage approaches may be optimal depending on geographic constraints.

Gender-differentiated analysis reveals important variations in market access outcomes. Female participants showed significantly stronger responses to collective marketing approaches (effectiveness coefficient 0.412 for women versus 0.287 for men, p=0.008 for difference), while male participants demonstrated stronger responses to direct buyer linkages (effectiveness coefficient 0.376 for men versus 0.214 for women, p=0.012 for difference). These gender differences have important implications for intervention design, suggesting that market linkage approaches should be tailored to gender-specific constraints and opportunities.

Price outcomes and negotiation dynamics represent critical dimensions of market linkage effectiveness (Table 10). Programs demonstrated different effectiveness in enhancing farmer bargaining position and price realization. Price satisfaction showed moderate variation across programs, with MADE participants reporting the highest satisfaction (52.5%) despite not achieving the highest absolute prices. GROW participants achieved the highest price premiums versus local markets (9.1% average premium) and highest reported price increases (70.0%) yet showed only moderate price satisfaction (47.5%). This paradoxical pattern suggests that price expectations may have been raised through program messaging about quality premiums, creating satisfaction gaps despite objectively better prices.

Table 10: Price Outcomes and Negotiation Indicators by Program

Indicator	MADE	ADVANCE	GROW	F-value/Chi-square	p-value
Price outcomes					
Price satisfaction (% satisfied)	52.5	39.4	47.5	3.11	0.211
Reported price increase (% reporting)	65.6	52.5	70.0	6.24	0.044
Price vs. local market (% premium)	6.3	4.2	9.1	5.87	0.003
Price stability (1-5 scale, 5=most stable)	3.2	3.7	2.9	8.43	<0.001

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Bargaining position					
Multiple buyer options (% reporting)	68.9	37.4	42.5	15.61	<0.001
Price negotiation (% able to negotiate)	57.4	31.3	63.8	20.65	<0.001
Market information access (1-5 scale)	3.6	2.9	3.8	11.32	<0.001
Rejection ability (% able to reject offers)	39.3	24.2	32.5	4.26	0.119

Price stability and predictability demonstrated important differences across market linkage models. ADVANCE's contract-oriented approach achieved the highest price stability ratings (3.7 on a 5-point scale) but the lowest reported price increases (52.5%). This stability-level tradeoff reflects a fundamental tension in market relationship design between price maximization and risk reduction. MADE's multiple buyer approach showed moderate stability (3.2) with moderate price increases (65.6%), while GROW's collective marketing without strong contractual frameworks showed the lowest stability (2.9) despite the highest price increases (70.0%).

Bargaining position indicators reveal substantial differences in negotiation dynamics. MADE participants reported greatest buyer choice (68.9% had multiple options) but moderate negotiation capability (57.4%). GROW participants reported highest negotiation capability (63.8%) despite more limited buyer options (42.5%), suggesting that collective marketing and better information access enhanced negotiation power despite fewer alternatives. ADVANCE participants showed the weakest negotiation position across all indicators, consistent with the program's emphasis on pre-established arrangements rather than spot market negotiation.

Market information access showed a significant correlation with negotiation capability ($r=0.643$, $p<0.001$) across all programs. GROW's stronger emphasis on market information provision (68.8% received information) corresponds with higher reported negotiation capability despite more limited buyer options. MADE's moderate information provision (59.0%) combined with greater buyer diversity created a different negotiation dynamic based more on alternatives than information advantage.

Gender analysis reveals significant differences in price outcomes and negotiation dynamics. Female participants showed lower price satisfaction across all programs (41.5% versus 58.0% for men, $p=0.007$) and reported weaker negotiation capability. However, these gender gaps varied significantly by program, with GROW showing the smallest gender differences in negotiation capability (57.5% for women versus 0% for men, as GROW had no male participants) and ADVANCE showing the largest gaps (18.2% for women versus 48.9% for men, $p<0.001$). These patterns suggest that market linkage approaches specifically designed for women may more effectively address gender-based negotiation constraints.

Output marketing strategies and outcomes is also an important factor. Output marketing strategies varied substantially across programs and regions, with important implications for smallholder commercialization and value capture (Table 11). Marketing strategies showed distinct patterns aligned with program approaches. ADVANCE participants demonstrated the highest reliance on storage for later sales (68.7%) and contract arrangements (45.5%), consistent with the program's emphasis on formal relationships and nucleus farmer aggregation. GROW participants showed an overwhelming preference for group marketing (81.3%) with limited storage for later sales (21.3%), reflecting both the program's collective emphasis and participants' limited storage capacity due to smaller farm sizes. MADE participants demonstrated the most diversified marketing strategies, with 67.2% practicing immediate sales while maintaining the highest average number of sales channels (2.3).

Table 11: Output Marketing Strategies and Outcomes

Indicator	MADE	ADVANCE	GROW	F-value/Chi-square	p-value
Marketing strategies (% practicing)					
Individual immediate sales	67.2	43.4	61.3	10.46	0.005
Individual storage for later sales	39.3	68.7	21.3	40.84	<0.001
Group Marketing	36.1	53.5	81.3	32.75	<0.001
Contract sales	24.6	45.5	20.0	15.82	<0.001
Marketing outcomes					
Multiple sales channels (mean #)	2.3	1.4	1.7	11.36	<0.001
Transaction costs (% of sale value)	6.3	8.7	5.2	7.42	0.001

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Reported market access improvement (%)	63.9	44.4	75.0	17.93	<0.001
Distance to point of sale (mean km)	8.4	4.7	5.6	7.82	<0.001

Transaction costs varied significantly by marketing strategy and program. Group marketing approaches facilitated by GROW achieved the lowest transaction costs (5.2% of sale value), primarily through shared transportation arrangements and bulk sales. ADVANCE's nucleus farmer model resulted in the highest transaction costs (8.7%), partly due to aggregation fees charged by nucleus farmers and transportation to designated delivery points that sometimes increased costs relative to local sales. MADE's market linkage approach achieved moderate transaction costs (6.3%) while maintaining greater marketing flexibility.

Market distance effects reveal important spatial dynamics in marketing strategies. MADE participants traveled furthest to reach points of sale (8.4 km on average) but reported the lowest ratio of farm-gate to market price differentials (12.3% versus 17.6% for ADVANCE and 16.2% for GROW). This suggests that direct buyer linkages facilitated by MADE reduced spatial price penalties despite greater distances, possibly through buyer-arranged transportation or price agreements that did not heavily penalize distance.

Crop-specific marketing strategies showed important variations. Soybean marketing demonstrated the highest group marketing participation (68.8%) and lowest immediate sales (38.8%), reflecting both higher value density that justifies collective marketing and greater female participation in soybean production. Maize marketing showed greater reliance on storage for later sales (55.0%) and moderate group marketing (44.3%). Rice marketing demonstrated the highest contract arrangements (54.5%) despite a small sample size, reflecting greater coordination requirements in the rice value chain.

Regression analysis of marketing outcomes indicates that market improvement perception is most strongly associated with price improvements (β=0.372, $p<0.001$), followed by reduced transaction costs (β=0.284, $p<0.001$) and increased buyer options (β=0.231, $p=0.002$). Marketing strategy diversity (number of channels) shows a positive association with reported income improvements (β=0.319, $p<0.001$), suggesting that flexibility and adaptability in marketing may contribute more to overall outcomes than any single marketing channel.

5. Discussion and Implications of Findings for Women Agri-Entrepreneurship Development

The comparative analysis reveals distinct advantages of gender-sensitive approaches to agricultural supply chain development. GROW's explicit focus on women farmers yielded superior outcomes in several dimensions despite targeting participants with more limited resource endowments. The program achieved the highest rates of improved agricultural practice adoption (78.8% for improved varieties, 71.3% for recommended agrochemical use), greatest post-harvest loss reduction (37.6% below baseline), and strongest market price improvements (9.1% premium over local markets). These outcomes suggest that gender-sensitive programming can overcome the resource limitations typically facing women farmers.

Several mechanisms appear to drive GROW's effectiveness with women participants. First, the program's intervention design directly addressed gender-specific constraints identified in the literature. The emphasis on labor-saving technologies responded to women's time poverty constraints documented by (Gebre et al., 2022). Secondly, GROW's training approach demonstrated greater effectiveness in knowledge transfer to women farmers. The program's more intensive training model (17.2 interactions per year) with emphasis on practical demonstration rather than theoretical instruction appears better suited to the learning preferences and educational backgrounds of women participants, 87.5% of whom lacked formal education.

Third, GROW's collective marketing approach showed particular efficacy for women participants, with 81.3% engaging in group marketing compared to 36.1% for MADE and 53.5% for ADVANCE. This collective approach appears to address women's specific market access constraints, including limited mobility, time constraints, smaller volumes, and weaker individual bargaining power. The effectiveness of collective approaches for women specifically supports findings by (Oduol et al., 2017) regarding the gender-differentiated benefits of group marketing in addressing structural constraints.

However, GROW's gender-sensitive approach demonstrated limitations in sustainability dimensions. Women participants showed greater dependency on program-facilitated market arrangements, with sharper declines in market access after program conclusion (45.0% maintained access versus 62.3% for MADE). This finding suggests that while gender-sensitive approaches can effectively overcome immediate constraints, additional attention to sustainable commercial relationship development may be necessary to maintain these benefits beyond the program timeframe.

Crop-specific adaptation similarly enhanced program effectiveness of GROW's program. GROW's emphasis on soybeans in the Upper West Region aligned with both agroecological suitability and gender-cropping patterns, resulting in 38.6% higher adoption rates compared to less context-adapted crop promotion efforts. Also, social context adaptation, particularly responsiveness to gender norms and local power structures, strongly influenced adoption and sustainability outcomes. GROW's adaptation to women's time constraints through appropriately scheduled training and activities achieved 76.3% participation rates compared to

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58.2% for less gender-adapted approaches. This finding reinforces research by Farnworth et al. (2020) demonstrating that gender-adaptive programming requires responding to specific contextual constraints rather than applying standardized gender approaches.

Infrastructure context adaptation showed particular importance for input supply chain development for women. Programs that modified distribution models based on road quality and market density achieved 46.2% better input availability compared to standardized distribution approaches. In areas with limited infrastructure, successful adaptations included mobile vendor systems (used by MADE with 63.4% coverage effectiveness) and village-based aggregation points (used by ADVANCE with 58.7% effectiveness). However, excessive adaptation presents risks of program fragmentation and implementation complexity, which can affect women participation.

Female market participation rates ranged from 68.3% in the Upper East to 42.5% in the Northern Region, reflecting different cultural constraints on women's mobility and market engagement. GROW's gender-focused approach showed the greatest effectiveness in the Upper East (83.3% market participation) compared to the Northern Region (50.0%), suggesting an interaction between program approaches and prevailing gender norms.

Traditional leadership structures influenced program implementation effectiveness. Communities with stronger traditional authority structures showed 43.7% higher adoption rates for new practices that received explicit chief endorsement. MADE leveraged this dynamic by systematically engaging traditional authorities (84.3% of implementation locations) compared to more limited engagement by ADVANCE (56.6%) and GROW (63.8%). This engagement pattern partially explains regional effectiveness variations, with programs showing stronger outcomes in areas where they aligned activities with traditional authority structures.

Religious factors affected program participation in complex ways. Muslim-majority areas showed 26.4% higher participation in financial service components but 18.7% lower participation in mixed-gender group activities. Programs demonstrated varying adaptation to these religious considerations, with GROW implementing women-only groups in Muslim-majority areas (achieving 87.5% participation) compared to mixed groups in other areas.

Social network configurations influenced information diffusion and technology adoption patterns. Communities with more centralized social structures showed more rapid initial adoption (57.3% first-year adoption versus 32.6% in less centralized communities) but more limited diffusion breadth (reaching 62.7% of potential adopters versus 84.5% in less centralized communities). ADVANCE's nucleus farmer model showed particular sensitivity to these network structures, with effectiveness varying by 47.3% between communities with different network configurations.

The findings demonstrated that direct provision approaches, exemplified most strongly by GROW, demonstrated superior immediate impacts on technology adoption rates. Improved seed adoption reached 78.8% under GROW's direct provision model compared to 62.3% for MADE's market facilitation approach and 35.4% for ADVANCE's hybrid approach. Similarly, recommended agrochemical use reached 71.3% under direct provision compared to 52.5% and 33.3% for market facilitation and hybrid approaches respectively. These adoption advantages appeared particularly pronounced for resource-constrained farmers, with direct provision showing 56.7% higher adoption among smallest-scale farmers (bottom quartile) compared to 28.9% higher adoption in the top quartile.

Market facilitation approaches, represented primarily by MADE, showed more modest immediate adoption impacts but substantially stronger market relationship development. MADE participants established an average of 2.8 commercial input supplier relationships and 3.2 buyer relationships, compared to 1.7 and 2.5 respectively for GROW's direct provision approach. These relationship indicators correspond with broader market engagement, with market facilitation participants utilizing 2.3 distinct sales channels on average compared to 1.7 channels for direct provision participants. The market relationship advantage appeared consistent across farm size categories, suggesting that market facilitation benefits were not concentrated among larger farmers as sometimes hypothesized.

Income effects showed more complex patterns across approaches. Direct provision generated higher immediate income increases for smaller-scale farmers (averaging 37.6% for the bottom quartile versus 29.4% under market facilitation), while market facilitation showed stronger effects for larger-scale farmers (averaging 42.8% for the top quartile versus 34.5% under direct provision). This crossover effect suggests important targeting implications, with direct provision potentially more appropriate for smaller-scale farmers facing multiple simultaneous constraints and market facilitation more effective for farmers with greater production capacity but limited market access.

Distributional equity analysis reveals important differences in who benefits from different approaches. Gini coefficients for benefit distribution (where higher values indicate more unequal distribution) averaged 0.32 for direct provision, 0.46 for market facilitation, and 0.41 for hybrid approaches. This distributional difference reflects both targeting approaches and inherent characteristics of the intervention models. Direct provision programs demonstrated a greater ability to ensure benefits reached smaller-scale and female farmers through explicit targeting and barrier-reduction approaches.

Analysis of post-program outcomes reveals significant differences in sustainability patterns between direct provision and market facilitation approaches. These differences manifest across multiple sustainability dimensions with important implications for intervention design and sequencing. Commercial relationship sustainability showed substantial

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advantages for market facilitation approaches. MADE participants maintained 73.8% of fertilizer access, 60.7% of improved seed access, and 68.9% of agrochemical access after program conclusion. These rates substantially exceeded sustainability under the direct provision, where GROW participants maintained only 37.5% of fertilizer access, 41.3% of improved seed access, and 45.0% of agrochemical access. This relationship sustainability advantage appears directly related to the market facilitation emphasis on establishing commercial connections rather than program-dependent provision channels. Group marketing arrangements established under direct provision showed 38.7% continuation rates compared to 62.3% for trader relationships established under market facilitation. Similarly, financial service arrangements showed 27.5% continuation under direct provision versus 54.1% under market facilitation. These institutional sustainability differences appear related to commercial viability for the non-farmer actors in these arrangements, with market facilitation approaches more explicitly addressing service provider incentives.

Analysis of sustainability determinants reveals that commercial viability for all value chain actors represents the strongest predictor of continued benefit streams (β=0.537, $p<0.001$). Direct provision approaches often created artificial economic conditions during implementation—such as subsidized services, guaranteed markets, or program-facilitated aggregation—that proved difficult to maintain without continued support. Market facilitation approaches that emphasized commercially viable arrangements from the outset demonstrated stronger sustainability despite more modest initial impacts. Cost-effectiveness analysis reveals complex tradeoffs between direct provision and market facilitation approaches that extend beyond simple per-beneficiary cost comparisons. These tradeoffs manifest differently across timeframes, outcome domains, and participant segments. Direct cost comparison shows substantial differences in per-beneficiary investment. GROW's direct provision approach costs approximately $587 per participant compared to $346 for ADVANCE's hybrid approach and $213 for MADE's market facilitation approach. These differences reflect both intervention intensity and the inclusion of physical inputs in direct provision programs. However, simple cost ratios provide limited insight without corresponding outcome measurements.

Additionally, income improvement cost-effectiveness shows different patterns. Each $100 invested generated approximately $184 in increased annual income under market facilitation compared to $163 under direct provision. However, this aggregate comparison masks important distributional differences. For the lowest-income quartile, direct provision generated $247 per $100 invested compared to $136 under market facilitation, while the pattern reversed for higher-income farmers. This crossover effect suggests that cost-effectiveness depends critically on participant targeting rather than being an inherent characteristic of either approach. Market facilitation approaches generated measurable spillover benefits to non-participants through market system improvements, with non-participants in MADE implementation areas showing 23.7% better market access compared to control areas. Direct provision approaches showed more limited spillover benefits (7.3% improvement for non-participants), concentrated primarily on knowledge diffusion rather than market system changes. Including these spillover effects in cost-effectiveness calculations increases market facilitation benefit-cost ratios to 5.3:1 while having minimal effect on direct provision ratios.

6. Conclusion and Recommendations

This comparative analysis of agricultural development programs in northern Ghana revealed several key findings regarding the opportunities in smallholder supply chain integration. In the first place, direct provision and market facilitation approaches demonstrated context-specific effectiveness rather than universal superiority. Direct provision showed stronger immediate adoption impacts and more equitable benefit distribution, while market facilitation yielded superior sustainability and stronger market relationship development. Secondly, gender-transformative approaches achieved superior outcomes for women farmers despite their limited resource endowments, through comprehensive attention to gender-specific constraints across supply chain segments. Thirdly, integrated approaches addressing multiple supply chain segments simultaneously demonstrated superior effectiveness compared to isolated interventions, though integration depth involved tradeoffs with coverage breadth. Finally, sustainability analysis revealed that commercial relationship establishment, credit arrangements, and supplier diversity served as critical predictors of continued benefit streams beyond program timeframes.

With the comprehensive findings, this study contributes to agricultural supply chain theory in several important dimensions. It challenges linear progression assumptions in smallholder integration models by demonstrating multiple viable integration pathways with different entry points. The findings refine scholarly understanding of gender dynamics in supply chains by showing how women's participation follows distinct patterns requiring specific support mechanisms. The study also contributes to collective action theory by identifying differential effectiveness factors for group marketing approaches across contexts.

Practical implications include the need for contextually tailored intervention approaches based on participant characteristics and regional conditions rather than standardized models. The research demonstrates that effective supply chain development requires strategic sequencing based on binding constraints rather than predetermined pathways. Findings support relationship-centered approaches over transaction-focused interventions, with an emphasis on establishing stable commercial relationships that persist beyond program timeframes. The study also reveals the importance of strategic subsidization as market catalysts rather than substitutes, and deliberate redundancy in market systems to enhance resilience against disruptions.

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Based on finding, the study provides a number of recommendations. Firstly, the study recommends that government and development should prioritize infrastructure investment that target critical market access constraints identified through systematic assessment of transportation barriers affecting smallholder commercialization. It is also recommended that regulatory frameworks should balance formal and informal seed systems to support both commercial and farmer-managed seed networks of women farmers while ensuring quality standards. Input subsidy programs should transition from direct distribution toward market-facilitating approaches that strengthen commercial distribution channels among women Agri-entrepreneurs. Extension services should be reconfigured to address gender-specific constraints through female agents, appropriate scheduling, and collective approaches that reach women effectively.

Irrespective of the robustness of the findings, this study faced some limitations that constrain inferential capabilities. The cross-sectional design limits causal attribution, necessitating caution in interpreting program effects. Potential selection bias exists due to non-random program assignment, though statistical controls partially address this concern. The post-program timing introduces variable recall periods and excludes examination of implementation processes.

Future research should employ longitudinal designs to track sustainability trajectories beyond the program conclusion. Comparative cost-effectiveness analysis incorporating both immediate and long-term outcomes would enhance understanding of investment trade-offs. Investigation of technology adoption dynamics should explore gender-differentiated pathways and social network effects on diffusion patterns. Additional research on optimal sequencing and combination of supply chain interventions would strengthen program design guidance. Finally, an examination of climate resilience dimensions in supply chain development could address emerging adaptation priorities in northern Ghana's changing environmental context.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

Data Availability Statement

Data is available on request from authors.

Abbreviations

ADVANCE	Agricultural Development and Value Chain Enhancement Project
ASD	Actellic Super Dust
FBO	Farmer-Based Organization
GHS	Ghana Cedis (currency)
GROW	Greater Rural Opportunities for Women
MADE	Market Development Program for Northern Ghana
MoFA	Ministry of Food and Agriculture
MS	Metal Silo
MT/ha	Metric Tons per hectare
NM	Neem (leaf powder)
PICS	Purdue Improved Crop Storage (bags)
PP	Polypropylene (bag)
SGB	Super Grain Bag
TFP	Total Factor Productivity
USAID	United States Agency for International Development
ZFB	ZeroFly Bag

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