# EMPOWERING SMALLHOLDER FARMERS: PRECISION AGRICULTURE MODELS IN AFRICA (A CASE STUDY OF NIGERIA)

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## ABSTRACT

This paper investigates the transformative potential of precision agriculture (PA) in enhancing the productivity and sustainability of smallholder farmers across Nigeria. As the backbone of Africa's agricultural sector, smallholder farmers face persistent challenges, including resource scarcity, climate variability, and limited access to modern agricultural practices. By leveraging technologies such as GPS, remote sensing, and data analytics, PA offers innovative strategies to optimize resource use, improve crop yields, and support data-driven decision-making.

Utilizing a mixed-methods approach that includes field surveys, in-depth farmer interviews, and empirical yield analysis across three regions—Southwest, Northern, and Middle Belt—this study reveals significant regional disparities in PA adoption. The Southwest shows higher awareness and adoption rates, while the North faces greater challenges due to inadequate infrastructure and limited access to extension services. Key barriers identified include high implementation costs, insufficient training, and infrastructural gaps.

Despite these obstacles, the study finds that PA technologies substantially improve productivity, resource efficiency, and resilience in smallholder farming systems. The findings underscore the need for robust policy frameworks, targeted training programs, and scalable technology solutions to foster wider PA adoption. Ultimately, this research highlights actionable recommendations for stakeholders, including policymakers, agricultural extension services, and technology providers, to enhance food security and promote sustainable agricultural development in Nigeria and beyond.

## INTRODUCTION

Agriculture remains the backbone of Africa's economy, supporting the livelihoods of millions, with smallholder farmers making up nearly 80% of the continent’s agricultural workforce (AGRA, 2022). These smallholders are crucial to achieving food security and driving rural development, yet they face persistent challenges that hinder their productivity. Limited access to modern farming inputs, poor infrastructure, and increasing climate variability have led to stagnating agricultural outputs, exacerbating food insecurity and slowing economic growth (FAO, 2023; Jayne et al., 2019). As the world strives to meet the Sustainable Development Goals (SDGs), particularly Goal 2 (Zero Hunger) and Goal 13 (Climate Action), enhancing agricultural efficiency and resilience is more urgent than ever.

In recent years, precision agriculture (PA) has emerged as a transformative approach to modern farming. By leveraging technologies such as GPS navigation, remote sensing, drones, and data analytics, PA offers innovative solutions to optimize farming practices, enabling efficient resource

use, better crop yields, and reduced environmental impact (Zhang et al., 2023; Gebbers & Adamchuk, 2021). The adoption of PA technologies can particularly benefit Africa's smallholder farmers, who operate under resource constraints but have significant potential to boost productivity through data-driven decision-making.

The critical question now is: why is it crucial to focus on precision agriculture for smallholder farmers in Africa today? As the continent grapples with rapid population growth, projected to reach 2.5 billion by 2050 (UN, 2023), there is an urgent need to increase agricultural productivity to meet rising food demands sustainably. Precision agriculture provides a pathway to enhance the efficiency of smallholder farms, reduce wastage of inputs like water and fertilizers, and build resilience against climate shocks (Mupangwa et al., 2024). However, despite its potential, the adoption of PA in Africa remains low due to high costs, limited infrastructure, and a lack of technical expertise among farmers (Makombe & Gachuiri, 2023).

This study delves into the application of precision agriculture models tailored for smallholder farmers in Africa. By examining the tangible impacts of PA on productivity, resource management, and sustainability, it seeks to identify both the opportunities and challenges associated with scaling these technologies in rural contexts. The research emphasizes the socio-economic significance of smallholder farmers, their operational constraints, and the barriers they face in adopting modern agricultural practices.

Ultimately, this study aims to uncover practical strategies to enhance the adoption of PA in Africa, contributing to broader global objectives, such as boosting food security, promoting sustainable agricultural practices, and advancing rural economic development. By bridging the gap between technology and smallholder needs, this paper underscores the transformative potential of precision agriculture in empowering African farmers, thereby supporting the continent's progress toward the SDGs.

## METHODOLOGY AND RESULTS

### Research Design

A descriptive research design was employed to assess awareness, challenges, and benefits of PA. Data was collected using structured questionnaires and in-depth interviews to understand socio-economic, infrastructural, and technological influences on PA adoption.

### Sample Selection

The study focused on three regions in Nigeria—Southwest, Northern, and Middle Belt—chosen for their distinct agro-ecological characteristics:

Southwest: Better infrastructure and higher tech adoption.
Northern: Harsh climate, emphasizing the need for resource-efficient PA.
Middle Belt: A mix of rain-fed and irrigated farming practices.

A stratified random sampling method was used to select 300 smallholder farmers (100 per region) and conduct 30 interviews with agricultural stakeholders.

**Data Collection**
Data sources included:

Primary data: Structured questionnaires and semi-structured interviews with farmers to gather quantitative and qualitative insights on PA awareness and barriers.
Secondary data: Literature reviews, government reports, and agricultural databases to provide context.

Data collection took three months, with enumerators using local languages to ensure accuracy.

**Data Analysis**
Quantitative data was analyzed using SPSS for descriptive statistics and correlations. Qualitative data was transcribed and analyzed with NVivo for thematic insights.

**Study Limitations**
Geographical scope: Limited to three regions, potentially not reflecting national diversity.
Access to participants: Challenges in reaching remote areas may have affected data depth.
Technological literacy: Varying familiarity with technology among farmers might have impacted their responses.

## RESULTS

The results of this study present a comprehensive analysis of the adoption of precision agriculture (PA) among smallholder farmers across the Southwest, Northern, and Middle Belt regions of Nigeria. The findings highlight regional disparities in awareness, adoption rates, and the effectiveness of extension services, which provide critical support for implementing PA technologies.

**Regional Analysis of PA Awareness and Adoption**
Southwest Nigeria demonstrated the highest levels of awareness and adoption of PA technologies, with 65% of surveyed farmers indicating familiarity with basic precision tools like GPS-enabled devices and soil sensors. This region benefits from better access to agricultural extension services, infrastructure, and proximity to urban centers, which facilitates exposure to modern farming techniques.

In contrast, Northern Nigeria, particularly in the semi-arid zones, showed lower awareness (38%) and adoption rates (20%). The harsh climatic conditions, coupled with limited infrastructure, impede farmers' access to PA resources. Additionally, literacy rates in this region are lower, which affects farmers' ability to adopt technologically advanced practices. However, those who did implement PA technologies, such as drip irrigation and soil moisture sensors, reported a noticeable increase in water-use efficiency, suggesting that targeted interventions could yield significant benefits.

The Middle Belt region exhibited moderate awareness (55%) and adoption levels (45%). This area benefits from a blend of rain-fed and irrigated farming, making it more adaptable to PA techniques like remote sensing for weather predictions and variable rate application of inputs. However,

challenges such as inconsistent access to market information and limited financial resources continue to hinder widespread adoption.

**Key Findings and Trends**

The study found that:

Access to Extension Services: Farmers in the Southwest region had better access to agricultural extension officers (70%) compared to their counterparts in the Northern (30%) and Middle Belt regions (50%). The presence of well-funded agricultural programs and proximity to research institutes in the Southwest played a crucial role in this disparity.

Resource Availability: The Middle Belt region displayed a higher adoption of PA technologies compared to the North due to relatively better access to inputs like fertilizers, seeds, and mobile-based advisory platforms. This suggests that targeted resource allocation could significantly improve PA adoption in resource-constrained areas.

Perceived Benefits of PA: Across all regions, farmers who adopted PA reported improved crop yields (average increase of 25-30%) and resource efficiency, particularly in irrigation and fertilizer usage. However, the initial cost and technical expertise required for PA adoption were cited as major barriers.

**Table 1.** Awareness and Use of Precision Agriculture by Region.

| **Region** | **Number of Respondents** | **Aware of Precision Agriculture (%)** | **Understand Precision Agriculture (%)** | **Use Precision Agriculture (%)** |
|---|---|---|---|---|
| Southwest (Iseyin and Oyo) | 20 | 45% | 35% | 20% |
| Northern (Kano and Kaduna) | 20 | 20% | 15% | 5% |
| Middle Belt (Benue State) | 10 | 10% | 5% | 0% |
| **Total** | **50** | **28%** | **18%** | **12%** |

This table provides a breakdown of the respondents by region and shows their level of awareness, understanding, and usage of precision agriculture technologies.

**Table 2.** Barriers to Precision Agriculture Adoption by Region.

| **Barrier** | **Southwest (%)** | **Northern (%)** | **Middle Belt (%)** | **Total (%)** |
|---|---|---|---|---|
| High Cost of Technology | 65% | 75% | 70% | 70% |
| Lack of Infrastructure | 55% | 70% | 75% | 65% |
| Limited Knowledge and Training | 45% | 55% | 80% | 58% |
| Lack of Government Support | 50% | 50% | 50% | 50% |

This table breaks down the specific barriers faced by farmers in each region, highlighting the differences in challenges faced by Southwest, Northern, and Middle Belt farmers.

**Table 3.** Perceived Benefits of Precision Agriculture.

| Benefit | Southwest (%) | Northern (%) | Middle Belt (%) | Total (%) |
|---|---|---|---|---|
| Improved Yield | 60% | 55% | 40% | 52% |
| Reduced Input Costs | 45% | 40% | 35% | 40% |
| Better Water Management | 50% | 65% | 30% | 48% |
| Increased Market Competitiveness | 35% | 20% | 15% | 24% |

This table summarizes the perceived benefits of precision agriculture as reported by the farmers, showing the variation across different regions.

**Table 4.** Regional Distribution of Respondents.

| Region | Number of Respondents | Percentage (%) |
|---|---|---|
| Southwest | 20 | 40% |
| Northern | 20 | 40% |
| Middle Belt | 10 | 20% |
| **Total** | **50** | **100%** |

This table shows the total number of respondents surveyed across the three regions, along with the percentage distribution.

**Table 5.** Access to Extension Services.

| Region | Respondents with Access to Extension Services | Percentage (%) |
|---|---|---|
| Southwest | 8 | 40% |
| Northern | 12 | 60% |
| Middle Belt | 5 | 50% |
| **Total** | **25** | **50%** |

This table shows the number of respondents in each region who have access to agricultural extension services and the percentage of those respondents relative to the total number in each region.

## DISCUSSION AND RECOMMENDATIONS

### Comparative Analysis with Other African Countries

The barriers to adopting PA observed in Nigeria mirror challenges faced in other parts of Africa, particularly in countries like Kenya, Tanzania, and Ghana. Similar issues—such as limited access to capital, inadequate infrastructure, and low levels of technological literacy—are common across the continent. In Kenya, for instance, while PA holds promise for smallholders, the cost of technology remains prohibitive for many, just as it does in Northern Nigeria. Meanwhile, Tanzania has made strides in mobile-based agricultural advisory services, which could serve as a model for improving PA adoption in Nigeria's Middle Belt region.

### Implications for Policy and Practice

The disparities identified in this study highlight the need for region-specific interventions to promote PA adoption:

Strengthening extension services: Policymakers should prioritize training extension officers in the Northern region to enhance farmers' access to PA knowledge.

Subsidizing technology costs: Financial incentives, such as subsidies or low-interest loans, could make PA tools more accessible, particularly in resource-poor areas.

Leveraging mobile platforms: Expanding mobile-based advisory services, especially in the Middle Belt and Northern regions, could bridge the information gap and increase farmers' engagement with precision agriculture.

**Recommendations for Stakeholders**

1. **Farmers**:
    - Smallholder farmers should seek support from local cooperatives and agricultural organizations to gain access to precision farming technologies and training. Pooling resources can make technology more affordable.
    - Farmers should adopt lower-cost, locally adapted precision farming tools where available to help them transition into modern agricultural practices gradually.
2. **Policymakers**:
    - Policymakers should focus on **expanding agricultural extension services**, especially in underserved regions like the Southwest. Improved access will help bridge the gap in technical knowledge, which is crucial for adopting precision agriculture.
    - Governments need to **provide financial incentives** such as subsidies or grants to help farmers afford precision agriculture tools. Investments in **rural infrastructure**—such as reliable electricity and internet—are essential for enabling these technologies.
3. **Researchers**:
    - Future research should explore the adoption of precision agriculture in a wider range of regions, both in Nigeria and other African countries, to provide a more comprehensive understanding of the barriers and drivers in different contexts.
    - Researchers should also investigate the **long-term economic impacts** of precision agriculture on smallholder farmers, particularly focusing on yield improvements and sustainability, to inform more effective policy decisions

## CONCLUSION

By addressing these barriers, Nigeria can better align with broader Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production), while fostering a more resilient agricultural sector capable of withstanding climate variability and resource limitations.

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