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Quantifying the impact of Agrotelematics: Exploring applications of information technology for agricultural development

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Abstract

This paper explores the concepts of agrotelematics as a transformative force in agricultural development, focusing on the adoption of information technology (IT) among farmers and its broader implications for the smallholder-driven agricultural systems. The study draws from a simulated scenario to illustrate the economics of IT adoption in enhancing agricultural development. The analysis illustrates significant improvements in productivity, income, and operational efficiency as a result of IT adoption by farmers. Notably, participating tomato farmers experienced a 95.7% increase in income and a 166.7% expansion in market reach, underscoring the capacity of digital tools to enhance agricultural outcomes. Additionally, reductions in transportation costs (−30%) and post-harvest losses (−52%) highlight improved operational efficiency. Overall, the analysis suggests that IT adoption produced economically meaningful benefits, reinforcing its potential as a transformative tool for smallholder farmers, and indeed, agricultural development, especially in Africa; where agriculture is predominantly smallholder-based, and constrained by limited access to capital, inputs, extension services,and untimely market information. These structural challenges, coupled with intense impact of climate change, require innovative and scalable interventions. Telematics, with its origins in the automotive sector, now presents a viable solution through real-time data capture, precision farming, logistics optimization, and decision support systems. To fully harness these benefits, targeted interventions are essential. The paper recommends expanding digital literacy programs to equip farmers with the skills needed to utilize agrotelematic tools effectively. Furthermore, policy-driven subsidies and financial incentives should be introduced to lower the cost barriers associated with digital technologies. Lastly, improving rural ICT infrastructure, particularly internet and mobile coverage, is crucial for real-time information flow and technology adoption. In conclusion, while telematics is still emerging in African agriculture, its potential to drive productivity, resilience, and market integration is substantial. With strategic investments and inclusive policies, agrotelematics can play a pivotal role in achieving food security and sustainable development across the continent.

Keywords: Agrotelematics; Information technology; Telematics; Agricultural development; Africa

1. Introduction

Agriculture plays a significant role in improving the economy of most African countries, and serves as the primary source of livelihood for the majority of the rural population in Africa (Unachukwu, 2025). Nevertheless, agriculture in Africa is predominantly driven by small-scale farmers, with women playing a significant role (Azumah *et al.,* 2023).

For many Africans, farming is more than just a business—it is a way of life deeply embedded in their daily routines and culture. However, despite its importance, agriculture in Africa remains underdeveloped, with inefficient food production, and primarily sustained by rural farmers, who are inefficient but constitute the majority of the farming

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population both in Africa and globally (Odusola, 2021). In general, agriculture in most African countries has been under-developed, traditional and largely localized. This makes technology a critical dimension for agricultural development in Africa. An improvement in this instance would constitute a model that enables a wider prospect in terms of providing technology driven information on agricultural operations, markets and innovations. Such technology has been described under the concepts of telematics.

Notably, information technology offers endless possibilities for improving agriculture in various ways (Tzounis *et al.,* 2017). for instance, recent advancement in information technology as applied to agriculture, has been a component of telematics, what has been code-named "agrotelematics", which has revolutionised agriculture and offered applied potentials for agricultural development, worldwide (Dichenskiy & Gritz, 2019). More so, the importance of information technology in helping to revolutionize agriculture in Africa, cannot be over-emphasized. Information availability and access remain critical to agricultural development, especially in Africa where technological advancement is yet to be fully achieved.Farmers' capacity to utilize specific knowledge and skills, such as adopting improved farming techniques and access to markets, is largely influenced by how easily they can access such information (Alhassan & Haruna, 2024).

In recent decades, against the norm of traditional agriculture, which has been the bane to food security in Africa, information technology serves to expose to a wider gradient, a volume of knowledge which has been useful for improving agriculture in different parts of the world including Africa. In fact, African farmers have relied on conventional farming systems handed-down for generations (Nkansah-Dwamena, 2024), while most of the farmers almost solely depend on their own field experience and superstition (Yang *et al.*, 2024; Wolf and Moser, 2011).

Moreover, the sharp rise in population and the resulting surge in food demand have intensified the need for rapid expansion of food production in Africa. In other words, the unprecedented increase in population has created emergencies in the food sector, spurring the need for increased food production (Bedasa & Bedemo, 2023). Nevertheless, increasing food access will mitigate all consequences of the projected population growth (as Adesete *et al.* 2023).

Africa has also been badly affected by numerous natural and environmental phenomena which have also contributed to food security emergencies, hence the need for a comprehensive cycle of innovative alternatives to help facilitate improved food production and indeed, agricultural development in the continent. These phenomena include the dreaded COVID 19 pandemic that did not only affect the health sector but also badly distorted the food production and supply system (Nekmahmud, 2024; Ryan *et al*., 2024; Boyacı-Gündüz *et al*., 2021). African countries are also facing the demeaning impacts of climate change (Adesete *et al*., 2023), as well as continuous negative impacts of crude oil and gas exploitation (Ukpong *et al.,* 2024).

To reiterate, the advent of information technology, and indeed, the application of concepts of information technology in agricultural farming and other agricultural practices, has expanded knowledge and skills which have helped to enhance agricultural development. With little or no advance technology, African farmers have over the years, been dependent on traditional and moribund farming systems, hence the sustained low and inefficient agricultural production in the continent. Thus, the benefits of agricultural technology, in improving agricultural development cannot be over emphasized.

With the growing demand for food triggered by unprecedented increase in population, farmers in Africa are saddled with the inevitable reality of the need to improve in food production. Again, the raging seemingly insurmountable problems facing agriculture in Africa, create the urgency to invest in agricultural technology, in a bid to enhance knowledge and skill for sustainable agricultural development in the African continent. The concepts of agricultural technology, or otherwise; telematics in agriculture (agro-telematics), have been highlighted in various literature; however, this paper aims at creating additional literary compendium and background by outlining topical concepts and discourse on important applications of agricultural technology. Specifically, the study highlights its information technology perspective, with a view to helping readers and stakeholders in agriculture, to further enhance knowledge and passion for agricultural technology as a critical model for agricultural development in Africa.

Furthermore, this paper encourages farmers in Africa to adopt and invest in agricultural technology, particularly information technology; by presenting a literature-based overview to expand awareness and highlight its potential and benefits for agricultural development. In particular, the discourse on agricultural technology is focused on the perspective of technology-driven information as facilitated by the concepts of telematics.

2. Concepts and Applications of Telematics in Agriculture

By definition, telematics is a term widely used to describe the technology that combines telecommunications and monitoring systems used in collecting and transmitting data over long distances. Telematics is an emerging technology (Whitcare et al., 2024), and has transformed agriculture by enabling precision farming solutions that optimize resource utilization, enhance productivity, and promote sustainability (Lajunen & Hovio, 2024). Application of telematics principles in agriculture has been commonly referred to as agrotelematics. As technology continues to evolve, the integration of telematics into agriculture and indeed, farming practices, will play a crucial role in meeting the growing demand for food while also minimizing the constraints posed by environmental impact and conventional farming systems.

Agrotelematics is a term commonly used to describe application of telematics concepts and principles in agriculture. As explained byBenos et al. (2022), agrotelematics encompasses the integration of telecommunications and information technology with agricultural practices, enabling farmers to monitor, manage, and optimize their operations in real-time. More so, agrotelematics has meteorological applications that helps farmers deal with issues of climate change and variability. For instance, with information technology, farmers can track and respond to the changes of weather (Benos et al., 2022).

Use of information systems, including mobile phones has helped to enhance small holder farmers' productivity (Mdoda et al., 2024). Similarly, as highlighted by Emeana et al. (2020), revolution of mobile phone-enabled services promotes agricultural development in Africa. Globally, adoption of agrotelematics is emerging and has become a critical tool for addressing agricultural challenges. This provides a renaissance for economic recovery and agricultural revolution, especially in Africa, where agriculture is a vital sector, employing more than 60% of the the workforce and contributing significantly to the GDP of many countries in the continent (Rafael, 2023; Jayne et al., 2021).

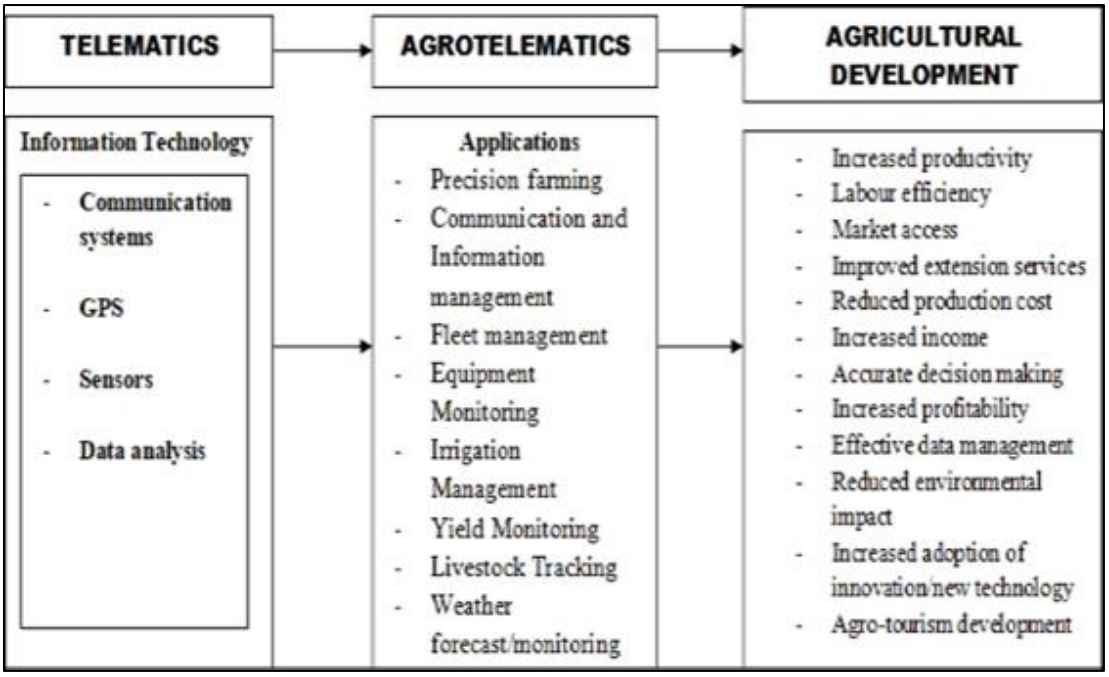
Telematics has components that enable its application in various sectors of the economy including agriculture. The key components are indicated in Figure 1. Telematics consists of communication technologies or communication systems such as cellular networks which enables point-to-point or human-to-human communications such as the mobile phones; satellite communications and other wireless media such as the Wi-Fi, which enables transmission of data from the field to a central system or domain. Information technology enhances communication and information dissemination among farmers, and the markets. The revolution in information technology has also enhanced improvement in extension service delivery; hence improving agricultural production, especially in the rural areas (Mapiye et al., 2025).

3. Telematics and Agricultural Development

Agricultural development refers to the process of improving the efficiency, productivity, and sustainability of agriculture to enhance food security, economic growth, and rural livelihoods (Alam et al., 2023; Rehman et al., 2022). It involves the adoption of modern farming techniques, improved seed varieties, irrigation systems, mechanization, and digital innovations to increase agricultural output. Additionally, agricultural development encompasses policy reforms, investment in rural infrastructure, access to credit and markets, and capacity building for farmers.

Sustainable agricultural development aims to enhance or balance economic profitability, resource efficiency, environmental conservation, and social equity by promoting climate-smart practices, efficient resource utilization, and resilience to climate change (Wang et al., 2024). It plays a crucial role in poverty reduction, job creation, food security, economic growth and overall national development, particularly in agrarian economies like those in Africa (Movilla-Pateiro et al., 2021).

Telematics has a wide range of applications in recent years. In particular, the application of telematics concepts in agriculture, (known as agrotelematics), has significantly advanced agricultural development in recent decades (Tankosić et al., 2024). This presents a unique technological opportunity that needs to be explored by farmers in Africa. Several common applications of telematics in agriculture are discussed in this section, and their implications for agricultural development are highlighted in Figure 1.



Source: author's framework based on conventional concepts,2024

Figure 1 Illustration of the relationship between telematics and agricultural development

As illustrated in Figure 1, precision agriculture: Telematics enhances precision farming by enabling the application of exact amounts of inputs like water, fertilizer, feeds, and pesticides, thereby improving productivity. Farmers collect vital data on weather, soil, crop health, and pest attacks for effective decision-making and resource management. Farm Equipment and Fleet Monitoring: Telematics allows real-time tracking and management of farm machinery, optimizing fuel use, improving performance, and reducing downtime through predictive maintenance. Irrigation Management: It supports soil moisture monitoring and automated irrigation, ensuring efficient water use and minimal waste. Tracking of Farm Animals: Farmers can monitor the location and health of livestock, improving herd management. Crop Yield Monitoring: Data from harvesters enable real-time analysis of crop yields, guiding future planting decisions. In addition, telematics enables renewable energy use in agriculture. For instance, internet of things (IoT) and artificial intelligence (AI), supports solar-powered irrigation, biogas, and smart farming systems, enhancing energy efficiency, reducing environmental impact, and promoting sustainable agricultural productivity.

4. Information Technology and Agricultural Product Marketing Efficiency

To further achieve the aim of this study in promoting adoption of agrotelematics towards enhancing agricultural development, an illustration of the impact of information technology on agricultural marketing, was explored by analyzing a case study of a Cooperative of 100 tomato Farmers over One Season, with approximate Effect Size (Cohen's d) measure for each metric. The simulation was based on indepth interviews and information supplied by tomatoes farmers contacted from Kano and Yobe States in Nigeria, as well as tomato traders in Uyo main market in Akwa Ibom State . Statistically, the Effect Size (Cohen's d) measure was explored, since other tests such as the paired t-test would not give a meaningful statistical difference between the 'before' and 'after' IT adoption data, due to the small sample size of the metrics ($n=6$), which could limit statistical power of the test. The Cohen's *d* test result is presented in Table 1.

Table 1 presents a hypothetical scenario and simulated case study of 100 tomato farmers over one season, showing the transformative impact of Information Technology (IT) on agricultural product marketing. As indicated, average Market Price per Kg increased by 22.2% (₦180 to ₦220), indicating improved price negotiation and access to better-paying markets through digital platforms. Average Volume Sold per Farmer rose by 31.3%, from 800 kg to 1,050 kg, due to enhanced logistics, market information, and demand forecasting. Transportation/Marketing Costs dropped by 30%, showing efficiency gains from IT-enabled route optimization and direct-to-market linkages. Market-Reach more than doubled (+166.7%), with each farmer now selling to 8 buyers instead of 3, thanks to digital marketplaces and social media. Post-Harvest Losses fell from 25% to 12%, a 52% reduction, driven by improved storage solutions and timely market access. Farmer Income nearly doubled (+95.7%) from ₦104,000 to ₦203,500, reflecting the combined benefits

of higher prices, lower costs, and increased sales volume. Overall, the data clearly demonstrate that IT adoption significantly boosts marketing efficiency, profitability, and sustainability in smallholder agriculture.

Table 1 Case Study Illustration: A Cooperative of 100 tomato Farmers over One Season, with approximate Effect Size (Cohen's d) measure for each metric

Metric	Before	After	% Change	Approx. Difference	Cohen's d (est.)	Interpretation
Market Price per Kg (₦)	180	220	+22.2%	40	≈ 1.00a	Large effect
Volume Sold per Farmer (Kg)	800	1050	+31.3%	250	≈ 1.25b	Large effect
Transportation/Marketing Cost (₦)	40,000	28,000	-30.0%	-12,000	≈ -1.20b	Large negative effect
Market Reach (Buyers/Farmer)	3	8	+166.7%	5	≈ 2.50c	Very large effect
Post-Harvest Loss (%)	25	12	-52.0%	-13	≈ -2.17c	Very large reduction
Farmer Income (₦)	104,000	203,500	+95.7%	99,500	≈ 2.30c	Very large effect

Note: Statistical Significance - aLikely statistically significant; bHighly statistically significant; cVery highly significant

These improvement can be attributed to IT Interventions, such as Mobile Market Platforms (e.g., facebook, whatsapp, AgroMall, FarmCrowdy etc), which enables direct market access and higher selling prices; GPS and Transport Apps, which promotes route optimization reduced logistics costs; IoT and Storage Technology, which helps to minimized post-harvest losses; digital extension services, which enhances improved timing and targeting of sales, and whatsApp/telegram marketing groups, which facilitates increased market visibility and number of buyers.

The Effect Size (Cohen's d) Cohen's d test result in Table 1 clearly shows economically and practically significant improvements. Note that the Cohen's d is a standardized measure of effect size; that quantifies the difference between groups or two means (before vs after) in terms of standard deviations (Kallogjeri & Piccirillo, 2023). The result shows a range: 0.2 = Small effect, 0.5 = Medium effect, 0.8 and above = Large effect, and > 2.0 = Very large effect. A positive value indicates an improvement/increase, while a negative value indicates a reduction based on the context. From the result, all metrics show statistically and practically significant differences between "Before" and "After" values. The effect sizes range from large (≈1.00) to very large (≈2.50), indicating meaningful improvements. Cost reduction and post-harvest loss improvements are particularly impactful, as shown by large negative effect sizes. Farmer income nearly doubled, supported by a very large effect size (≈2.30) — a strong indicator of program or intervention success.

The effect sizes are mostly large to very large, justifying the conclusion that IT adoption had a substantial positive impact on tomato farmers. Despite small sample size used for the illustration, the economic magnitude of change is very clear; indicating that income almost doubled, market reach nearly tripled, and post-harvest losses cut by more than half, while marketing costs dropped significantly. This suggests practically meaningful benefits from IT adoption, regardless of what a formal p-value might say. The visual presentation of these changes is shown in Figure 2.

The analysis and accompanying chart clearly demonstrate that the adoption of IT solutions by a cooperative of 100 tomato farmers led to substantial improvements across key agricultural and marketing metrics. The most striking gains were seen in market reach and farmer income, which increased by 166.7% and 95.7% respectively; indicating broader buyer access and enhanced profitability. Additionally, reductions in transportation costs (−30%) and post-harvest losses (−52%) highlight improved operational efficiency. Overall, the evidence suggests that even in the absence of statistical significance due to sample size limitations, IT adoption produced economically meaningful benefits, reinforcing its potential as a transformative tool for smallholder farmers, and indeed, agricultural development.

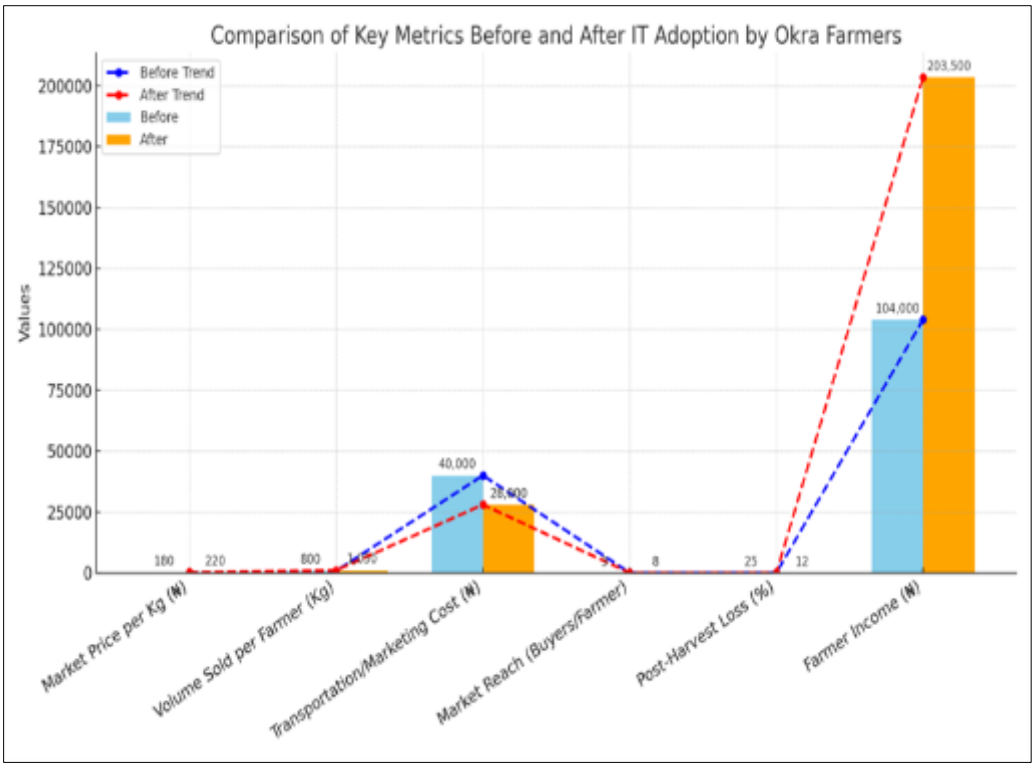


Figure 2 Graphical illustration of the comparison of key metrics indicating before" and "after" IT adoption by small scale tomato farmers

5. Conclusion and Recommendations

This paper reviews the impact of IT adoption among farmers and illustrates the broader implications of telematics for African agricultural development. The study was meant to promote IT adoption by smallholder farmers, revealing strong improvements in productivity, income, and efficiency, demonstrating the transformative potential of digital technologies for smallholder farmers.

African agriculture is largely dominated by smallholders, who operate at the most basic level of production and face multiple constraints such as low capital, limited access to modern equipment, poor market information, and inadequate extension services. These challenges, compounded by the effects of climate change, highlight the urgent need for innovative technological interventions.

Telematics, originally applied in the automotive industry, has emerged as a powerful tool in agriculture. It enables precision farming, improves data-driven decision-making, reduces losses, and boosts overall productivity. In particular, IT-based systems enhance market access, reduce post-harvest losses, and streamline logistics, as seen in the case of the tomato farmers whose income rose by 95.7% and market reach expanded by 166.7%.

The technological transformation of agriculture in Africa is critical for food security, poverty reduction, and sustainable rural development. However, barriers such as high initial costs, limited digital literacy, and poor infrastructure must be addressed to unlock the full potential of agricultural technologies.

Recommendations

- Expand Digital Literacy Programs: Government and NGOs should invest in training programs to build farmers' capacity to understand and use digital tools effectively.
- Subsidize Access to Agricultural Technologies: Provide financial support or subsidies to smallholder farmers for purchasing digital devices and accessing agri-tech platforms.
- Strengthen Rural ICT Infrastructure: Invest in rural internet connectivity and mobile network coverage to ensure reliable access to real-time agricultural information and market data.

- Foster institutional collaboration: Encourage partnerships between farmers' cooperatives and academic institutions to leverage Technical and Vocational Education and Training (TVET) innovations as a complementary source of affordable agricultural technologies and support services

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