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A Techno-Economic Feasibility Study for Integration of Satellite Technology in Agriculture for Uganda

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ABSTRACT

In Uganda, agriculture employs over 80% of the workforce and contributes significantly to GDP. However the industry faces persistent challenges including low productivity, climate variability, and limited access to timely agricultural information. Satellite technology has the potential of being a transformative opportunity for addressing these constraints. This study explores the possibility of integrating satellite technologies in agriculture for Uganda. An interdisciplinary methodology combining space, business and agricultural domains consisting literature review and field surveys revealed low adoption rates despite high interest among farmers. Findings underscore the role of satellite data in yield prediction, crop health monitoring, and weather indexing. Policy gaps, limited technical infrastructure, low human expertise and low awareness in Uganda are identified as key barriers. The study therefore proposes a scalable business satellite services model tailored for Uganda's diverse agricultural stakeholders identifying key revenue streams. Strategic recommendations for improving access, policy, and stakeholder engagement to scale satellite-based agricultural services, positioning Uganda for a digitally-enabled, climate-resilient agricultural transformation are discussed.

INTRODUCTION

Background

Agriculture continues to be the cornerstone of Uganda's economy and the primary source of livelihood for its population. As of 2022, approximately 66.26% of Uganda's working population was employed in the agriculture sector (World Bank, 2023). Furthermore, the sector contributed 35% of the country's export earnings during the same period (International Trade Administration, 2023). However, only approximately 44% of Uganda's arable land is currently under cultivation (Food and Agriculture Organization, 2023). While all this is however realized, the sector faces several challenges such as unpredictable weather patterns, soil degradation, pest infestations, and inefficient resource utilization (Nile Post, 2024). The agricultural landscape in Uganda is beginning to witness a transformation through the adoption of various digital tools that aim to modernize farming practices and improve market efficiencies. These technologies range from basic mobile applications to sophisticated satellite-based systems, offering solutions across the agricultural value chain. With the increasing penetration of technology across the country, mobile applications and digital platforms are emerging as powerful tools for farmers. Applications like AgriPredict and EzyAgric provide farmers with real-time data on critical aspects such as weather patterns, effective pest control methods and recommended best farming practices (Youth in Agriculture and Agribusiness Investment Coalition (YAIC), 2025).

Despite the clear benefits and successful implementations of ICT platforms and digital tools in Ugandan agriculture, the overall adoption rates remain relatively low, indicating a significant untapped potential (Journal of Applied Sciences, Information and Computing, 2023). For example EzyAgric has so far registered only 300,000 farmers and have 20% active engagement with the platform (Taylor & Francis, 2020), (Sasakawa Africa Association, 2022), (CGIAR, 2024) due to the fact that most ICT usage by farmers is still dominated by basic mobile phone uses and radio for information dissemination. (Byamukama *et al.*, 2022), (Kansiime *et al.*, 2022).

Precision agriculture is therefore a key component of sustainable agricultural systems in the 21st century. It entails a management strategy that uses a suite of advanced information, communication, and data analysis techniques in the decision making process which helps to enhance crop production, reduce water and nutrient losses and counter negative environmental impacts. It however requires large volumes of high resolution that can be derived from remote sensing systems (Rajendra *et al.*, 2020).

Therefore satellite technology through its applications of earth observation/remote sensing and global navigation satellite systems (GNSS) then becomes a pivotal and unavoidable solution to the existing agricultural challenges, offering unparalleled capabilities for crop health monitoring, soil analysis, yield prediction, early threat detection and climate impact assessment over vast areas (United Nations Office for Outer Space Affairs, 2025). This satellite application works in a way that the onboard

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high-resolution cameras that take images of various areas of interest on earth during a satellite pass over the ground. Satellite earth observation employs two sensor types namely: passive and active sensors. Passive sensors, like Landsat's multispectral and hyperspectral instruments use natural radiation to assess crop health, identify diseases, gauge nutrient deficiencies. Thermal sensors (also passive) monitor heat emissions for water stress and drought detection. Active sensors, such as Synthetic Aperture Radar (SAR) on Sentinel-1 and LiDAR, an active laser-based sensor technology, generate their own signals, allowing data capture regardless of cloud cover. They measure soil moisture and crop structure terrain analysis with a degree of accuracy. Complementing this, Internet of Things (IoT) devices provide ground-level data, while cloud computing handles massive datasets, and Geographic Information Systems (GIS) integrate all spatial information for advanced agricultural analytics (EOS Data Analytics, 2025).

During crop production, satellite data can facilitate precision agriculture through vegetation indices such as the Normalized Difference Vegetation Index (NDVI), enabling real-time monitoring of crop health , crop yield prediction and early detection of stress from pests, diseases, or nutrient deficiencies. This data-driven approach allows for targeted input application, reducing costs and minimizing environmental impact (Rajendra *et al.*, 2020). Post-harvest handling and agro-processing also benefit from satellite monitoring. Additionally, satellite-enabled logistics monitoring improves supply chain efficiency by identifying bottlenecks and optimizing transport routes (Cherlinka, 2024).

Market access is another critical area where satellite data proves valuable. By analyzing infrastructure, market locations, and price trends, satellites facilitate better integration of rural producers into urban and export markets. Demand forecasting tools supported by remote sensing help producers align supply with market needs, reducing price volatility and improving profitability (Lelechenko, 2024).

Satellite-based crop monitoring has evolved into a mature technology with demonstrated capabilities across diverse agricultural systems and environmental conditions. Contemporary approaches leverage multispectral and synthetic aperture radar (SAR) sensors to derive vegetation indices and biophysical parameters that characterize crop health, growth stages, and stress conditions. The most widely adopted vegetation indices include the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil-Adjusted Vegetation Index (SAVI), each offering distinct advantages for different crop types and growth stages (Deshpande *et al.*, 2025). High-resolution satellite systems have demonstrated particularly strong performance for crop monitoring applications. Sentinel-2 imagery, with its 10-meter spatial resolution and 5-day revisit time, has proven effective for field-scale monitoring in smallholder systems. Al-Gaadi *et al.* (2016) reported that Sentinel-2-derived NDVI and SAVI indices achieved prediction errors of only 3.8-10.2% for potato yield estimation, outperforming the coarser Landsat-8 imagery which showed errors of 7.9-13.5%. The integration of SAR data with optical imagery has emerged as a critical advancement for all-weather monitoring capabilities, particularly important in tropical regions with persistent cloud cover addressing a fundamental limitation of optical sensors in cloud-prone regions, making it particularly relevant for equatorial countries like Uganda.

Across Africa, there's a growing recognition of satellites as vital decision-aid tools for enhancing food security.

Countries like South Africa, Egypt, Nigeria, Algeria, and Kenya have launched multiple satellites for Earth observation. (Businessday NG, 2025). Uganda also launched its first satellite, PearlAfricaSat-1, with missions explicitly aimed at agricultural enhancement, alongside climate and disaster management (Omara *et al.*, 2022). This research investigates the viability, feasibility, and transformational potential of satellite-based agricultural services in Uganda through an interdisciplinary methodology by examining the existing landscape of implementation for remote sensing technologies while evaluating the commercial viability of bundled satellite services for the agricultural community of Uganda.

To the best of our knowledge, no similar studies for Uganda have been carried out providing such a view. In this paper, the closest related work in the recent literature are two surveys about agricultural monitoring using earth observation in Africa (EO-NAM Research Team, 2024), (Nakalembe *et al.*, 2021) some studies of remote sensing system application for climate or agriculture in other African countries (Nakalembe *et al.*, 2025), (Liepa, Thiel, *et al.*, 2025) and evaluation of digital technologies for agriculture (Fuentes-Peñailillo *et al.*, 2024), (Mollel *et al.*, 2025), (Ozor *et al.*, 2025). Our work differs from the mentioned papers because we narrow down the study focus to Uganda considering satellite technology solutions applicable to the country's existing agricultural problems and we employ a multifaceted approach in our study combining all relevant factors.

A comparison table between the present contribution and the related work in terms of covered topics and methodologies is provided in Table I. These related studies unifiedly reveal initial existing gaps such as limited farmer-level impact, adoption and interest rather than the focus on governmental and institutional adoption. Eyes in the Sky, Boots on the Ground (Lobell *et al.*, 2020) conducted in Eastern Uganda, comparing various ground-based yield measurement techniques with satellite-derived data. Using a strong methodology, utilizing gold-standard full-plot harvests as a benchmark to compare farmer-reported data and sub-plot crop cuts, it reveals that farmer-reported yields are significantly biased, often doubling the actual measured yield. It demonstrates that satellite measures explain as much variation in "true" yield as objective crop cuts do.

A comparison of these studies revealed the following gaps for Uganda.

• There is no clear, peer-reviewed techno-economic analysis for Uganda that quantifies investment costs, operating costs, revenue streams, and investor returns for satellite EO services in Uganda therefore, insufficient evidence exists to state profitability or required capital at scale for Uganda.

• Current studies assess technical accuracy and pilot services but do not provide representative adoption rates or business performance metrics across farmer populations in Uganda

• There is need for integrated trials that link accuracy to monetization. Very few studies track how improved remote sensing accuracy translates into farmer willingness-to-pay, service uptake, or measurable income gains; this gap constrains business model validation.

• There is lack of high-quality, publicly available in situ ground truth data hindering advancement of satellite-based quality research in Africa.

Contributions of this paper

Our contribution can be summarized as follows;

• Firstly we propose an interdisciplinary methodology combining business, earth observation, and agricultural perspectives, thus advancing a systematic approach to studying satellite technology adoption in low and middle-income agricultural contexts.

• Secondly we provide original survey data on Ugandan stakeholders' awareness, readiness, and perceived challenges regarding satellite-based agricultural applications addressing a critical knowledge gap in regional and global literature.

• Lastly we develop actionable, evidence-based recommendations for policymakers, government agencies, industry, academia and farming communities in Uganda.

Table 1: Comparison between the existing studies with this paper.

Reference	Year	Scope
(Fuentes-Peñailillo *et al.*, 2024)	2024	Global Context, Comprehensive study of IoT, UAV, AI technologies in Agriculture.
(Nakalembe *et al.*,2025)	2025	Senegal Context, EO Capabilities, Study on Climate Trends.
(Lobell *et al.*, 2020)	2020	Ugandan Context, Satellite data effect on crop yield.
(Nakalembe *et al.*,2021)	2021	African Context with a mention of existing Ugandan systems, EO Capabilities, Agricultural monitoring.
(EO-NAM ResearchTeam, 2024	2024	African Context, EO Capabilities, Policy & Financial considerations, Monitoring framework.
(Mollel *et al.*, 2025)	2025	African Context, Comprehensive of Digital technologies in Agriculture, Farmer based solutions.
(Ozor *et al.*, 2025)	2024	AI Integration & Applications, African Context, Policy and Gender Focus.
(Nakalembe *et al.*,2023)	2024	African Context, EO Capabilities, Policy & Financial considerations, Commercial Private Space sector.
This Paper	2025	Ugandan context, Business integration, EO Capabilities, Empirical Data from farmers, Customised solutions.

MATERIALS AND METHODS

This research study involved extensive literature review of peer-reviewed academic publications, industry reports, news articles, government reports and sampled data collection of selected farms and expert consultations in the agriculture, business, satellite technology fields. The study was strategically performed from these three different perspectives in order to understand the interdisciplinary factors that influence embracement of satellite applications for Agriculture in Uganda.

PRISMA 2020 reporting guidance was used to document the identification, screening, eligibility assessment, and inclusion of the reviewed literature in a transparent and reproducible manner. The resulting evidence base was then synthesised with Uganda's regulatory context, utility conditions, and infrastructure constraints to identify priority interventions, sequencing logic, and readiness conditions for phased implementation.

LITERATURE REVIEW

The literature search was first conducted through a systematic search of academic databases and relevant institutional repositories. Key databases included IEEE Xplore, Google Scholar, Scopus, and Web of Science. To get better results in these large databases, some keywords were used to find relevant studies to the topic of study such as satellite applications in Uganda, Agriculture in Uganda", "food security, agricultural innovation, earth observation in Africa, satellite technology in Uganda. The second channel of literature search was through a review of industry reports, news articles, blogs, magazines, and government publications in Uganda, majorly available open source, ministry repositories, and various organization websites. Additional search keywords used included technology in agriculture, economic trends in agriculture,challenges faced by farmers. The search focused on studies carried out and published information between 2020 and 2025 not excluding a few foundational papers in the area of study. Initial search yielded 207 papers. After screening titles and abstracts against inclusion criteria (peer-reviewed, relevant to satellite agriculture in Uganda and Africa), 105 papers were selected for full-text review. Priority was then given to papers that had a clear differentiation on general crop production and use of satellite technology excluding those focused on one crop. Final synthesis included 25 papers.The review synthesized findings, identified recurring themes, noted limitations in existing work, and pinpointed specific gaps addressed by this project.

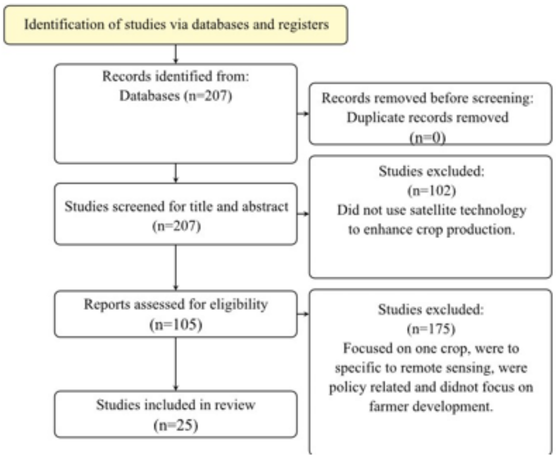

Figure 1: PRISMA flow diagram summarizing the literature search

Agriculture sector in Uganda

Challenges faced by farmers practicing large scale agriculture in Uganda were investigated, innovative technological practices undertaken to enhance crop production and studies carried out to identify factors influencing Ugandan farmers' intake of new technologies. Quarterly and yearly evaluation reports by agricultural organizations and institutions (private and public) were reviewed to identify general patterns and performance of the agricultural sector in Uganda. The search reviewed studies that investigated the business viability, feasibility of technology application to enhance farmers'yield and profits. To contextualize our findings within Uganda's agricultural sector, we employed PESTEL analysis that identifies enablers and barriers to satellite technology uptake."

Satellite applications in agriculture

This review gathers relevant information on EO (earth observation), IoT and their applications in agriculture. Reports from the few space companies in Uganda or companies that use satellite imagery, government bodies' publications were reviewed to assess the progress on the adoption of satellite technology in agriculture in Uganda. A comparative analysis of the EO service providers in Uganda was performed to evaluate their capabilities in solving agricultural problems. Various case studies on satellite technology application in agriculture from other African countries such as Algeria, Egypt, Kenya, Nigeria and South Africa were analyzed to draw lessons, best practices and assess EO service offerings that could inform Uganda's adoption strategy.

Data Collection

The data collection process involved surveys, interviews and physical visits as detailed below.

Survey questionnaire

We designed a structured open-ended questionnaires based on the literature reviewed and used a qualitative approach to capture diverse stakeholder perspectives. The questionnaire was pre-tested among 5 farmers in Buikwe district thus rectifying the identified inconsistencies prior to the actual data collection. The questionnaire aimed to assess awareness, adoption levels, and perceived value of satellite-based agricultural services among farmers. The greater discussions were held with farmer groups to understand their specific needs, preferences, and concerns. The surveys were disseminated via social media platforms mostly while others were conducted via phone interviews. The questionnaire targeted smallholder farmers evenly distributed across 5 districts (Kampala, Mukono, Wakiso, Luwero and Masaka) whose demographics are shown in Table II. These farmers were purposively selected based on the crop they were growing. The first survey collected responses from 60 respondents distributed as 75% being small holder farmers, 16.7% governmental agricultural organizations and the rest of the 8.3% spread across the NGOs, farmer groups, commercial farmers and private agricultural focused institutions.

Physical visits

Lastly, the data collection process also involved physical visits of two randomly selected large scale crop farms located in Kampala and Luweero (Uganda's Central region) respectively holding in person farmer interviews to understand their specific needs, their satellite technology awareness, perceived value of satellite-based agricultural services and financial, technical capabilities of satellite technology integration in their day to day

Table 2: Demographics of Farmer Respondents

Variable	Frequency	Percentage
Farm size < 1 acre 1 - 3 acres 5 - 10 acres	29 21 10	48.1 35.3 16.6
Farming Type Crop farming Mixed farming Livestock	30 25 5	50 41.2 9.8
Crop type Maize Cassava Beans Coffee Others (Rice/Beans/ Vegetables)	16 8 9 18 9	26 13 15 30 16
Farming Practice Rainfall Manual Watering Irrigation	41 13 6	67.6 20.6 11.8

operations. The two farms consisted of crops such as described in Table II being cultivated on 4 and 8 hectares respectively. Ethical concerns were considered during all data collection activities to ensure the integrity of the research process. Verbal informed consent was obtained from all respondents, who were provided with clear explanations of the study's purpose, their rights, and how their data would be used. Participation was voluntary whilst ensuring anonymity.

Business Perspective

Following collection of data, Porter's Five Forces analysis examining supplier and buyer bargaining power, industry rivalry, substitute threats, and entry barriers served as an external diagnostic tool. These findings underpinned the development of a Lean Canvas, which mapped critical strategic components for satellite integrated agricultural services.

RESULTS AND DISCUSSIONS

The results obtained from the literature review, online survey and the informant interviews have been gathered into the following sections as shown below.

Survey results

Farmers' challenges: Figure 2 illustrates the farmer reported agricultural challenges and losses in the survey comparing the percentage of farmers who reported each challenge with those who experienced actual losses.

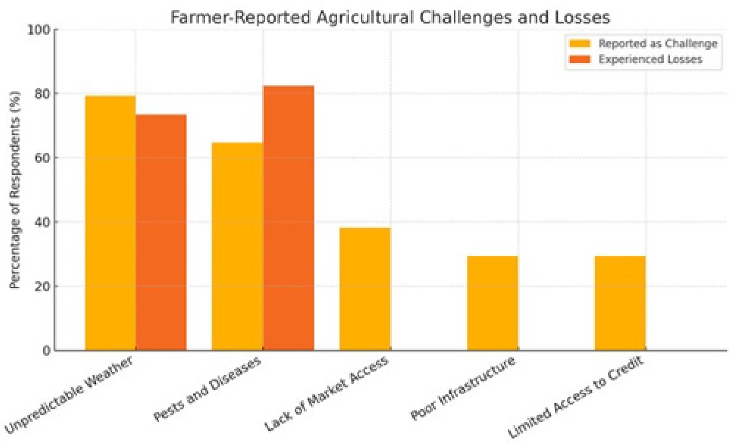

Figure 2: Farmer Reported Agricultural Challenges and Losses

Technology Usage: The current usage of technology in agriculture such as remote sensing applications or drones by the farmers was found to be low among the survey participants. They attributed this low adoption to high cost, lack of awareness, no training or exposure, and absence of accessible platforms. While the willingness is high, the mentioned challenges remain a hindrance. The survey revealed several insights into farmers' use of technology in agriculture as described in Table III In terms of weather monitoring, 41.2% rely on observing natural indicators such as cloud patterns while for pest and disease detection, 47.1% depend on visual inspection and 23.5% use local or indigenous knowledge to estimate crop yields.

Table 3: Technology Usage among Farmers

Variable	Category	Frequency
Use of Technology	No technology used Smartphones/Mobile applications Computers/Tablets	58.8 35.3 5.9
Perceived Effectiveness	Very effective	50.0

Willingness to integrate technology into agriculture: The greater percentage of farmer groups was more receptive to adopting the new technologies. The results showed that there is a large unfamiliarity with the technology application for Agriculture in Uganda, and the willingness of farmers to adopt innovations like satellite services goes beyond their ability to understand the technology but involves deeply rooted cultural beliefs, social norms, and local practices that shape their perceptions and choices. The findings also revealed that the corporate agricultural organisations, business entities and NGO support groups are willing to pay for crop monitoring, pest and disease control, and weather forecasting. The highest perceived value lies in real-time monitoring and climate resilience tools as all stakeholders want actionable hyper-local data to make more informed decisions in their farming.

Willingness to integrate satellite technology: The survey revealed the following insights as described in Table IV. When some local agriculture based entities were approached to determine their willingness to invest in satellite based technologies, they expressed great positivity and had the willingness to explore the precision agriculture platform capability, farm input management, satellite-based weather and yield prediction. They also cited climate change adaptation, supply chain optimization, and farm risk management as key areas where satellite data can be integrated.

Table 4: Willingness to Integrate Satellite Technology Among Farmers

Variable	Category	Frequency
Awareness	Heard of it Not heard of satellite technology	20.6 79.4
Interest in Learning	Interested in learning more Not interested	94.1 5.9
Perceived Potential	Believes it can solve farming challenges Do not believe	97.1 2.9
Likelihood of Adoption	Very likely to adopt Unlikely or would not adopt Neutral	64.7 11.8 23.5

Financial ability: The average budget that farmers and agricultural entities allocate to technological services ranges from Shs.200,000 to Shs. 10,000,000,000 which brings this to an average estimate of around Shs. 320,000,000 of the research sample space. Also important to note, 40% of the research sample space did not have any budget allocated to technological services. Most commercial banks in Uganda offer tailored microfinance products for farmers and medium loans to large-scale agribusiness ventures. In rural communities, SACCOs (Savings and Credit Cooperative Organizations) and village savings groups provide smaller, community-based loans. However, systemic challenges remain: high interest rates, collateral requirements, low financial literacy, and poor access to credit histories prevent many farmers from benefiting fully. However, some respondents were also concerned about the inadequate funding policies where to address clear financial mechanisms geared towards these satellite services and technologies such as incentives and subsidies or credit access for farmers. The survey findings also showed that about 63.9% either had no idea about or disagreed with the possibility of there being any local or international grants or incentives available for agricultural innovation or technology adoption.

Social challenges: Some of the social factors highlighted included low levels of education, skepticism in the ability of new technologies and peer influence on the trending technologies. Slightly more than one-third (36.4 percent) of the respondents admitted to economic pressures and social status playing its part in affecting their adoption to these advanced technologies. Another significant factor mentioned was the limited awareness and accessibility to this information. Figure 3 shows the social challenges faced by the farmers affecting satellite adoption in their practices. The results show that the high cost of the technology is still a major hindrance for adoption considering their salary earnings. Moreover, while most farmers possess smartphones, they lack consistent internet to use satellite technology. The results also show that the new technology would require vigorous training that might demotivate the farmers' adoption of the technologies. Finally, the results indicated that half of the participant farmers are skeptical of the ability of the satellite data to enhance their crop production and solve their existing challenges

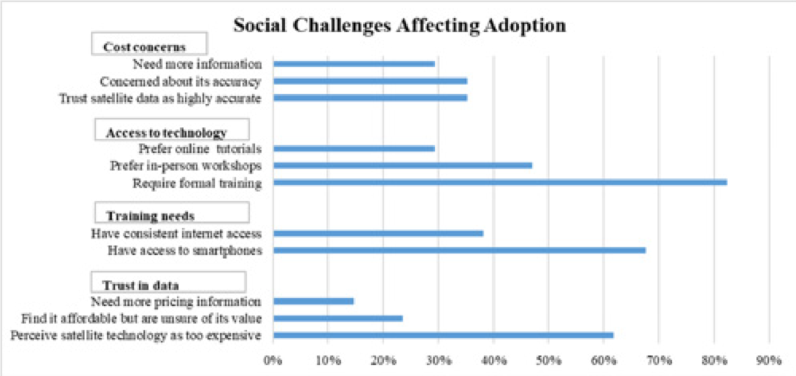

Figure 3: Social Challenges concerning Satellite Adoption

Policy knowledge and implications: The survey showed that 86.1 percent of the respondents welcomed the idea of establishing agricultural regulations for Uganda that affect the adoption of advanced technologies, mentioning that these would encourage innovation and research while the other 13.9 percent showed concern towards the lack of specific provisions in the regulations that explicitly address satellite-based technologies which creates uncertainty for providers and also highlighted the bureaucratic hurdles, lengthy approval processes, excessive licensing requirements for satellite technology providers delaying implementation and increasing costs.

Results from the Literature Review

Agricultural state of Uganda

Uganda's agricultural sector is characterized by smallholder dominance, subsistence orientation, and mixed cropping systems that present both opportunities and challenges for satellite technology integration. Understanding these systems is essential for designing contextually appropriate interventions. The "Uganda Agri-Economic Outlook" (April 2024) from Agroberichten Buitenland (a publication by the Netherlands Ministry of Agriculture, Nature and Food Quality) highlights that Uganda's most valuable agricultural sub-sectors include coffee, maize, aquaculture, tea, bananas, livestock, oil seeds, rice, and horticulture among others (Netherlands Ministry of Agriculture, Nature and Food Quality, 2024).

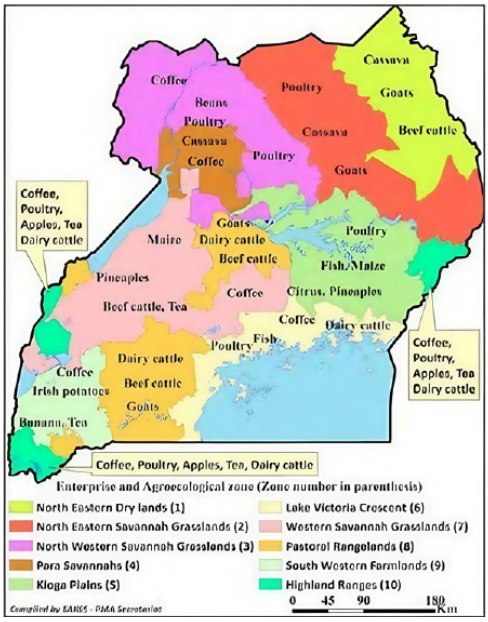

Figure 4: Map of Uganda's agro-ecological zones

The study identified different types of agricultural entities that operate to enhance agricultural productivity in Uganda. Table V below lists examples of these major entities grouped in five main categories as shown below. These stakeholders will be the primary users of satellite technology for agriculture.

Uganda's agricultural production targets as elaborated Uganda's Vision 2040 include focusing on increasing productivity, ensuring food security, and enhancing agro-processing. Key goals include boosting agricultural output, improving nutrition, promoting environmental sustainability, engaging youth in agriculture, and integrating advanced technologies. The strategy emphasizes value addition, market access, and climate resilience to support economic growth and rural development. By leveraging innovation and sustainable practices, Uganda aims to transform agriculture into a modern, competitive, and inclusive sector that contributes significantly to national development and poverty reduction Government of Uganda, 2013.

Uganda's Parish Development Model (PDM) aims to transform subsistence households into the money economy, making the parish the hub for grassroots planning and resource delivery. It emphasizes agricultural value chain development, financial inclusion via Parish SACCOs, and community mobilization (Mergers & Inquisitions, 2024).

Table 5: Agricultural entities in Uganda

Type of Organization	Organizations
Farmer Groups, SACCOs and Cooperatives	Teso Farmers Agribusiness Centre (TEFAC) (Teso Farmers Development Initiative, 2025) Simbya Farmers Cooperative Society (Simbya Financial Cooperative Society Limited, 2025) Uganda National Farmers Federation (UNFFE) Uganda National Farmers Federation, 2025 Bugisu Cooperative Union (BCU) (Advocacy Coalition for Sustainable Agriculture, 2025)
Governmental Bodies	Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF) (Ministry of Agriculture, Animal Industry and Fisheries, 2025) National Agricultural AdvisoryServices (NAADS) (National Agricultural Advisory Services, 2025) National Agricultural Research Organisation (NARO)
NGOs	Field of Hope (Field of Hope Uganda, 2025) Advocacy Coalition for Sustainable Agriculture (ACSA) (Advocacy Coalition for Sustainable Agriculture, 2025) Eco-Agric Uganda (EcoAgric Uganda, 2025) Heifer International (Heifer International Uganda, 2025)
Research organizations	The Nine Uganda Zonal Agricultural Research and Development Institutes (ZARDIs) under NARO (NARO, 2025b) MUK Agricultural Research Institute Kabanyolo (MUKARIK) (Makerere University, 2025b) The Seven National Research Institutes (NARIs) under NARO (NARO, 2025a)
Agriculture-focused Financial Institutions	Centenary Bank Pride Microfinance Agro-Insurance Consortium Uganda Insurers Association (UIA) Agricultural Credit Facility (ACF) Centenary Bank, 2025; Pride Microfinance Limited, 2025; Uganda Investment Authority, 2025

Uganda's agricultural sector however faces profound challenges despite vast arable land (Food and Agriculture Organization of the United Nations, 2024). Productivity growth (2% annually) lags population growth (3.3%), highlighting a critical performance gap (African Leadership Magazine, 2025). Climate change, with droughts and floods, causes substantial economic losses and threatens future crop values (Foresight4Food, 2025). Land degradation is widespread, impacting soil fertility and national GDP (Food and Agriculture Organization of the United Nations, 2025). Inadequate infrastructure, including poor roads and limited storage, leads to high post-harvest losses and quality issues like aflatoxin contamination, resulting in export rejections (World Bank, 2025). Farmers struggle with limited access to affordable credit and unreliable inputs, hindering technology adoption (Akanmu, 2025). Weak extension services and policy implementation bottlenecks further impede progress (Lwanga, 2025). High-value subsectors grapple with distinct challenges: coffee suffers low yields (Mutegi *et al.*, 2025) ; maize battles mycotoxins (Tibagonzeka *et al.*, 2018); aquaculture faces fingerling/feed shortages (Kasozi *et al.*, 2024); bananas contend with pests/ diseases and market power imbalances (Kiiza *et al.*, 2004); livestock is hit by climate-induced diseases (Food and Agriculture Organization of the United Nations, 2024); oil seeds are affected by procurement delays (Mukasa, 2025) ; rice struggles with low yields and input access (Barungi & Odokonyero, 2016); and horticulture deals with low yields and market access limitations (Kazibwe, 2025). A holistic, multi-stakeholder approach is crucial for sustainable transformation. A 2022 study in Journal of Multidisciplinary Studies analyzed smallholder farms in Eastern Uganda, reporting that over 50% of farmers experienced crop losses ranging between 50% and 100% of expected output due to flooding. The study also highlights that Eastern Uganda's floods cause over USD 62 million in agricultural GDP losses annually, alongside property and infrastructure damage (Kongai *et al.*, 2022). A risk assessment study published in 2015 reveals that drought was identified as Uganda's most damaging natural hazard, with average annual losses estimated at approximately USD 44.4 million (Taghouti *et al.*, 2015).

Technology adoption in the agriculture sector

The government of Uganda, along with development partners, has established several grants and incentives aimed at promoting innovation in agriculture. Notably, the Uganda Agricultural Insurance Scheme (UAIS) offers subsidized insurance products to help farmers manage climate-related risks. The Uganda Development Bank (UDB) provides concessional financing options targeted at agribusinesses incorporating modern technology. NARO (National Agricultural Research Organization) also plays a central role by supporting public-private innovation projects and piloting research-based solutions. Additionally, international development agencies including USAID, IFAD, and the European Union regularly fund digital agriculture and climate-smart agriculture programs. In some cases, tax incentives are available to agricultural startups through the Uganda Investment Authority (UIA). Despite this ecosystem of support, uptake is often constrained by bureaucratic processes, limited awareness among farmers, and weak institutional capacity to absorb and deploy innovations effectively.

Uganda's digital agriculture landscape has evolved rapidly in recent years, with multiple platforms and initiatives targeting smallholder farmers, though significant gaps in coverage and functionality persist. Mobile phone penetration provides foundational infrastructure for digital agriculture. Willbroad et al in (Willbroad *et al.*, 2023) identified mobile phones and radio as the leading ICT types used for disseminating agricultural information in Uganda, recommending prioritization of these platforms for effective information dissemination. (Ajambo *et al.*, 2022) examined innovations in digital agriculture platforms for rural finance and logistics in Uganda's agrifood sector, highlighting challenges affecting production and incomes where most of the population is employed in agriculture thus provided insights into Uganda's digital agriculture landscape and empirical case studies of platform implementation. Susan in (Susan, 2025) investigated smallholder farmers' access to the EzyAgric digital agriculture platform in Uganda, identifying financial constraints, limited digital literacy, and lack of trust as key barriers, with women facing additional challenges like financial dependency and elderly farmers preferring traditional methods. IoT and sensor-based systems are also emerging but face adoption challenges. Researchers have carried out studies to evaluate the impact of IoT-based soil moisture sensors on maize yield in Eastern Uganda's smallholder farms in relation to smart irrigation solutions.

Satellite technology in agriculture for Uganda

In Uganda's Third National Development Plan (NDPIII) (2020/21–2024/25) and Uganda Vision 2040, satellite technology is explicitly recognized as a critical enabler of development to a middle-income country however, there is not yet a central focus on space science and satellite technology as standalone sectors (National Planning Authority, 2023).

Uganda has actively been building its own space capabilities right from 2022 through the Ministry of Science, Technology and Innovation (MoSTI) from its participation in the multinational BIRDS-5 program in 2022 where it launched PearlAfricaSat-1, its first satellite, carrying payloads for multispectral imaging aimed at soil fertility and land-use analysis, all driving efforts towards the development of the agricultural sector (Omara *et al.*, 2022). Uganda has also recently demonstrated significant commitment to developing its indigenous space industry through its active participation in the African Development Satellite Project (AfDev-Sat). The AfDev-Sat initiative is a joint Earth Observation mission whose payloads are a 7-metre resolution panchromatic camera and a 30-metre multispectral camera, designed to operate for two years. The data collected by these instruments will support critical applications such as climate monitoring, agricultural development, and disaster management for Uganda (Space in Africa, 2025). This hands-on involvement is a positive step towards localising satellite manufacturing, assembly, integration, and testing capabilities within Uganda thereby fostering technological self-reliance and strengthening national capability (Space in Africa, 2025).

For the private sector, GTS solutions, a private technology company founded in 2007 based in Kampala, Uganda focuses on agricultural technology solutions but recently ventured into satellite imagery for precision agriculture solutions like crop monitoring using and data analytics (GTS Solutions, 2025). Environmental Surveys, Information, Planning and Policy Systems (ESIPPS) is another earth observation and geoinformation solutions company that provides local and international level environmental consultancy services targeting agriculture, wetland vulnerability analysis, climate change and disaster risk reduction. (ESIPPS International, 2025). Finally, NileOrbital Aerospace is a Ugandan space technologies start-up company founded in 2023 with the aim of developing local space capacity (NileOrbital Aerospace, 2025). It holds annual engineering internships in conjunction with the academic staff at Makerere University championing innovation and space education for satellite applications in the country.

In Uganda, projects like MUIIS and SUM Africa have successfully demonstrated the use of satellite-based advisory services to improve yields (Benjamin, 2020) and support climate risk management for smallholder farmers (Food and Agriculture Organization, 2019). The MUIIS project provided over 250,000 farmers with satellite-based weather forecasts, agronomic advice, market information, and index-based insurance. Managed by Ensibuuko, the subscription-based service led to yield increases of up to 67% and income gains of 70%, highlighting the impact of bundled, data-driven advisory tools (Benjamin, 2020). The SUM Africa project offered satellite-enabled index insurance using rainfall and drought data from Meteosat and CHIRPS. Run by eLEAF, it employed a B2B and B2C model where local insurers and agribusinesses delivered insurance products to farmers. With government-backed premium subsidies, it reached over one million Ugandan farmers, reducing vulnerability to climate-related risks (Food and Agriculture Organization, 2019).

Uganda's Disaster Risk Financing Program provides a rare operational example of satellite-triggered financing at scale. Nakalembe (2026) documented that the program (2016-2020) used MODIS vegetation indices for drought response, supporting over 452,000 people. The program demonstrated that data-triggered financing can operate within government institutions, though sustainability faced institutional and financial barriers. The study emphasized that successful replication requires prioritizing institutional architecture and sustained financing over technical perfection, providing critical lessons for scaling satellite-based risk management systems. The Climate-Variability Impact Index represents another approach to integrating satellite and meteorological data for agricultural monitoring. Zhang *et al.* (2005) developed methods for monitoring crop production using satellite-based climate variability indices, though specific performance metrics were not detailed in available metadata. Jiang *et al.* (2022) incorporated weather indexing using Growing Degree Days (GDD), Heating Degree Days (HDD), and Cold Accumulation Temperature (CAT) in their ZZTop-LSTM model, demonstrating the value of phenologically-relevant weather indices for yield prediction.

Policies such as agro-insurance presented by The Uganda Insurers Association as a private partner implementer of the Uganda Agriculture Insurance Scheme (UAIS), which offers weather based index insurance service at subsidized rates for the insurance premiums where part is paid by the government utilizes the satellite technologies jointly with the District's Average area yield determined over several years as a benchmark to provide coverage for losses due to extreme weather patterns such as drought. (United Nations Office for Outer Space Affairs, 2025)

Emata, a digital credit platform, uses satellite and weather data to assess creditworthiness for smallholder farmers. By digitizing farm data through cooperatives and integrating satellite-informed production forecasts, Emata offers affordable loans via mobile platforms like WhatsApp, maintaining a default rate below 1% (FSD Uganda, 2024).

Together, these initiatives showcase how integrating satellite technology into digital service models can improve yields, manage climate risks, and expand access to finance offering scalable solutions to transform Uganda's agricultural sector sustainably.

The farmers that participated in this survey when asked also suggested that the developed satellite-based agriculture technology should have the following features:

- It should be able to provide weather forecasts, crop monitoring updates, pest and disease monitoring and soil health monitoring.
- It should have a mobile application with SMS capabilities with a connection to farmer cooperatives.
- It should provide frequent updates preferably on a daily basis.
- It should have a bilingual capability with an element of Luganda complemented with English.

The higher education sector and research capacity in Uganda is growing steadily, evidenced by various space projects undertaken by undergraduate and postgraduate students at Makerere, Busitema, Mbarara, ISBAT universities among others. The Aeronautics and Space Bureau has heavily invested in research projects and locally organised events attracting discovery and innovation among the country's scientists thus equipping our human capital workforce for satellite application development. The establishment of the Agricultural Policy Research Centre at Makerere University in 2025 also further strengthens the country's capacity for customizing satellite applications to developing context-specific solutions.

Factors Affecting Satellite Technology Adoption in Agriculture

1. Policy Integrating satellite data into agriculture for any country is greatly hinged on enabling policies to facilitate this development. The created formal national space policy framework shall support satellite applications in agriculture. The Aeronautics Bureau's mandate is "to coordinate and facilitate research, development of innovations in space technology with an inclination to earth observation systems. Uganda still lacks a directly targeted policy for space innovations and satellite technologies or one that governs spatial data sharing which restricts its development of the sector. (Aeronautics and Space Science Bureau, 2024). Normally, government agencies set up national data-sharing arrangements, which control the routine flow of satellite imagery and derived information to farmers and extension services. Satellite agriculture services are controlled and must also align with broader policies. For example, according to the Data Protection and Privacy Act of 2019, satellite data is allowed to be collected as long as authorized by the law but cautions data collectors against gathering and processing personal data in a manner that infringes on the privacy of the data subject (National Information Technology Authority—Uganda, 2019). According to the National Agricultural Extension Strategy of 2016/2017 financial year to 2020/2021, a sustainable mechanism for packaging and disseminating appropriate technologies to all categories of farmers and other beneficiaries in the agricultural sector was emphasized, thus promoting the incorporation of modern technologies such as the satellite services. The Agro-insurance policy issued by The Uganda Insurers Association offers weather based index insurance service that utilizes the satellite technologies to determine compensation for losses caused by extreme weather conditions (International Fund for Agricultural Development, 2024). This policy provides subsidized rates for the insurance premiums where part is paid by the government and therefore also facilitates the use of satellite technologies in Uganda while improving the livelihood of the farming groups. The lack of no directed policy concerning remote sensing applications poses another significant obstacle for navigating the regulatory landscape within Uganda. This absence has led to fragmentation in data acquisition processes, missed opportunities for public-private partnerships. This policy vacuum also limits national budgetary prioritization, discourages investment, limits coordination among government agencies, research institutions, and private sector actors making it difficult to embed satellite data workflows into national agricultural systems and decision-making processes (United Nations Economic Commission for Africa, 2020). Currently, every satellite operator or service provider has to obtain an operation license from the Uganda Communications Commission (UCC) and ensure compliance with related regulations before putting any technology product on the Ugandan market (Uganda Communications Commission, 2022).

2. Social factors of deployment Deployment and adoption of satellite-based agricultural technologies in Uganda is not determined by technical feasibility alone but rather can be deeply influenced by a set of interrelated social factors of how farmers perceive, access and use these innovations. A good holistic understanding of these social dynamics is essential to ensure a seamless implementation of satellite services to the country's smallholder farmers. A fundamental obstacle to satellite adoption in Uganda is the generally low level of awareness of space knowledge among country citizens at large. As shown in the survey results, smallholder farmers, agricultural experts have little experience with usage of satellite data for farming. This is also evidenced by a very low number of active earth observation government projects in Uganda each annum and similarly very few private companies designing or applying such technologies [less than 10 known registered companies in the entire country]. This knowledge gap severely limits demand-side engagement and impedes the development of market-ready EO solutions tailored to Uganda's agricultural context. Without targeted awareness campaigns and educational outreach, the transformative potential of satellite data remains largely untapped.

3. Cost of Satellite Technology Cost is a central determinant in the deployment and sustainability of satellite technologies within any African country. As Uganda prepares itself to integrate space-based systems into national development, adequate and well-structured financing both at institutional (public & private) and end-user levels (farmers) is essential to ensure that such technologies transition from pilot initiatives to practical tools for agricultural transformation. In this context, the financial ecosystem for satellite applications must align with the socio-economic realities of Uganda's agriculture communities. Despite global trends toward open-access EO platforms like NASA's MODIS, ESA's Sentinel, many high-resolution datasets critical for crop analysis remain prohibitively expensive for most Ugandan institutions. The cost of commercial SAR satellite imagery is valued at \$15–30 per square kilometer (Huang *et al.*, 2025) depending on resolution and licensing terms, making routine acquisition financially unsustainable for the Ugandan economy without donor support or multilateral subsidies. Another financial burden associated with processing, and maintaining the satellite data also restricts its use to well-funded organizations, thereby perpetuating inequities in access to digital agricultural innovations. Lastly, the substantial capital investment required for satellite development and launch, along with establishment of the necessary ground infrastructure also significantly limits entry. These high costs discourage local innovation, as the technology developers are constrained by the availability and affordability of foundational data inputs.

4. Infrastructure for Processing and Analysis of EO Data The inherent complexity of satellite technology and its production demands high capabilities and preparedness for any country. The effective use of satellite data requires robust digital infrastructure, including high-speed internet, data storage servers, geospatial laboratories, and advanced computing capabilities for data processing and modeling. In Uganda, much of this infrastructure remains underdeveloped, particularly outside major urban centers. The country also lacks state-of-the art facilities for assembly, testing and production of satellites therefore hindering our independence to operate our own earth observation missions increasing reliance on external data. The country still has many areas without access to reliable internet and a stable supply of electricity (The EastAfrican, 2024), (Murungi et al., 2025) disabling the farmers from easily accessing satellite data, using the technology that requires connectivity and powering any devices needed to interact with satellite-based technology systems. Effective use of satellite data demands not only technical infrastructure but also institutional coordination. In Uganda, siloed data management practices among government ministries, research institutions, and development partners often result in duplication, data loss, underutilization of existing assets, impedes collaborative efforts and reduces the overall utility of satellite data. There is currently no centralized data-sharing platform in Uganda that mandates interoperability across agencies therefore data gathered by one institution may not be visible or accessible to others, leading to inefficiencies and missed synergies. This institutional fragmentation was noted by stakeholders during our study, many of whom highlighted the need for standardized metadata protocols, interoperable platforms, and national geospatial data repositories.

5. Limited Trained Technical Capacity in the Country Developing and deploying advanced satellite systems necessitates significant technical expertise and continuous investment in research and development to stay competitive in a rapidly evolving technological landscape. However, there is currently a very low number of qualified professionals in the space industry or related fields where it can be applied that are capable of acquiring, interpreting, and operationalizing satellite-derived information. While Uganda has made progress through implementation of advanced graduate academic programs at Busitema, Makerere Universities and other technical collaborations (Aeronautics and Space

Science Institute, Busitema University, 2025), (Makerere University, 2025a), the number of professionals with specialized training in remote sensing, GIS, and EO analytics remains insufficient relative to demand. This is evidenced by the lack of certified specialised space training institutions, advanced courses in Ugandan universities that train satellite technologies & applications and lack of space education in lower education (primary and secondary schools). A shortage of professionals with experience and a sustainable system to build a continuous skilled workforce in satellite engineering, hinders industry growth for a country. This human capital gap continues to stall the development of local innovation ecosystems that could build and deploy EO applications for agriculture at scale.

Business Perspective

The economic viability of satellite agriculture services depends fundamentally on developing sustainable business models that balance cost recovery with accessibility for resource-constrained farmers. Different business models were discovered during the review each with varying implications for scalability and sustainability in developing country contexts. Public-private partnership models offer an alternative approach that combines government support with private sector service delivery. Nakalembe *et al.* (2024) proposed a framework for EO-based National Agricultural Monitoring (EO-NAM) for the African context, emphasizing that robust systems require significant investments in human capacity and technology adoption. The framework advocates for phased implementation, suggesting a hybrid model where governments provide foundational infrastructure and capacity while private actors deliver specialized services.

Proposed satellite services Business model

A lean canvas was therefore developed to capture the business case that was derived from the data collected as explained in Table VI. It emphasized identifying and addressing key assumptions and risks associated with new business ideas. The Lean Canvas comprises nine essential elements: Problem, Customer Segments, Unique Value Proposition, Solution, Channels, Revenue Streams, Cost Structure, Key Metrics, and Unfair Advantage (Moshood *et al.*, 2021).

Financial model

A financial model was then used to estimate the necessary cash flows, financing requirements, and valuation for a startup company that would be interested in implementing a satellite technology for agriculture in Uganda. A mixture of references, anecdotes from the data collected and educated assumptions were used to derive a basic income statement financial model projecting five years of operation as shown in Table VII.

The model assumes that the company starts with a seed investment of $ 150,000 and is able to capture 0.3% of Uganda's market in a period of 5 years with an annual 60% revenue growth. Revenue is earned through the three revenue streams highlighted in the lean model with subscription fee is $ 7 per acre per year, average pay-per-use fee is $ 500 per use and average project consulting fee is $ 5,000.

Discussion And Analysis

Satellite Technology Pipeline

The results above suggest that satellite technology can be instrumental in addressing most of the challenges faced by the agricultural sector and eventually lead to increased productivity across all sub-sectors if leveraged correctly. Table VIII below matches each individual challenge with a satellite-based solution.

The results also highly indicate that satellite technology adoption in agriculture is not very popular in Uganda. In the event that a satellite services provider were to establish themselves, Figure 5 below illustrates a proposed service delivery model explaining how the satellite provider associates with other various vertical service providers throughout the entire delivery chain to the last mile of the farmers.

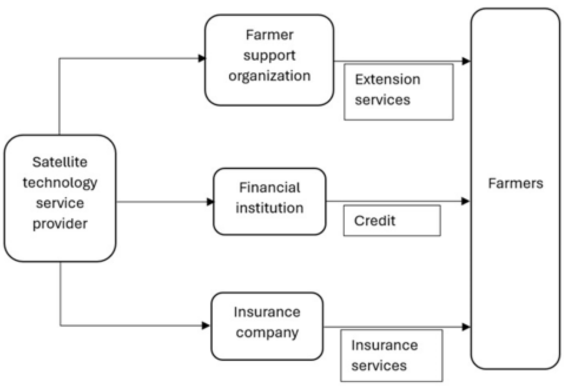

Figure. 5: Satellite technology-to-farmer delivery model

The satellite technology service provider consumes satellite data from existing providers therefore operating downstream as opposed to upstream which would require using proprietary satellites. The proposed satellite service model can seamlessly integrate with Uganda's Parish Development Model directly supporting Pillar 1 (Agricultural Value Chain Development) by optimizing farming practices and Pillar 6 (Parish-Based Management Information System) by feeding accurate, up-to-date agricultural data, strengthening planning, monitoring, and financial allocation through the Parish Revolving Fund, ultimately boosting farmer incomes.

The results also indicate there is low knowledge of satellite technology among the farmers. The capacity building system in Uganda is currently still in its early stages indicating need for research and innovation among the country's scientists to strengthen the country's capacity for customizing satellite applications. Inadequate skilled personnel greatly hinders growth of satellite technology in the country.

Table 6: Satellite Based Agriculture Project Business Canvas

Problem	**Solution**	**Key Metrics**	**Unique Value Proposition**
Insufficient local and sustainable satellite technology service provider	Bundled all-encompassing downstream satellite technology service	Subscribers, requests, yield improvements, insurance & credit uptake, revenue growth	A 360-degree coverage of all applications of satellite technology in agriculture with direct human contact where necessary
Unfair Advantage	Customer Segments	Channels	Revenue Streams
Localized	Smallholder farmers, Commercial farmers, Food processors, Policymakers, Financial institutions, Research institutions	Digital Cooperatives, Agro-input Financial Government, programs platforms, SACCOs, dealers, institutions, Extension	Subscription fees, Pay-per-use fees, Contract payments

Cost Structure: Satellite data acquisition, software services, cloud hosting, software development and maintenance staff, data analytics staff, customer support & training, marketing & outreach, agronomy staff, accounting & finance staff, administrative and customer support staff.

Table 7: Business Financial Model

Years	**Year 1 ($)**	**Year 2 ($)**	**Year 3 ($)**	**Year 4 ($)**	**Year 5 ($)**
Revenue	85,000	137,500	200,000	325,000	525,000
COGs	28,000	42,000	56,000	84,000	140,000
Gross profit	57,000	95,500	144,000	241,000	385,000
Total expenses	118,194	122,050	149,946	166,082	206,528
EBIT	(61,194)	(26,550)	(5,946)	74,918	178,472
Net profit	(61,194)	(26,550)	(5,946)	52,443	124,930

The literature clearly shows that satellite industry of Uganda is in its initial stages with less than 5 years of space development presenting a unique opportunity for the locals including investors, space professionals and the general public to venture in the industry with less competition and room for exploration. The Ugandan government's recognition of digital agriculture as a key development priority shall also provide a supportive environment for policy creation for satellite applications. From the projects studied in other African state countries, it is undoubtedly clear that leveraging more partnerships with other states has great potential to reduce costs, combine different expertise and infrastructure, accelerate technology adoption and use international cooperation to achieve a common African goal of development of the Agriculture sector using space technology. Uganda's participation in remote sensing regional initiatives like the Digital Earth Africa platform and SERVIR Eastern and Southern Africa program also provides the country with more practical experience to scale these initiatives and to orchestrate other partnerships.

Business work plan

The business model derived is for a privately owned satellite technology service provider company that serves farmers in a business-to-business (B2B) format as illustrated in Figure

The financial model shows that an initial investment of $150,000 would be sufficient to start the company and guarantee a positive cash position for a period of 5 years if no aggressive capital expenses are incurred after the first year. Considering the potential impact of the company, $150,000 is a relatively small investment. The success of the company would also depend on the effectiveness of automation, capability of the team, the growth of the customer base and measurable significant positive impact on the users' productivity.

The business and financial models show that with the existing average Ugandan limited farmer budgets and high data acquisition costs, satellite adoption in agriculture at a large scale still presents significant challenge. Porter's Five Forces analysis of the proposed business model reveals a dynamic and evolving competitive environment. The sector faces growing rivalry from global and regional players offering satellite-based services, driven by innovations and the demand for precision farming tools. Farmers and agricultural stakeholders currently have limited bargaining power due to low digital literacy and adoption, but this is expected to improve with greater awareness and value-added services. Overall, success in this sector hinges on cost-effective service models, local partnerships, and the ability to deliver actionable insights that directly improve farming outcomes. Foreign investment may be a potential ladder for the success and expansion of the earth observation projects. This amount can easily be raised by combined effort of a group of investors. Over the past 5 years, there is an increasing trend of foreign investors from the US and Europe with the ability to cover the cost of starting up companies in Africa, for example in Rwanda, South Africa, Ethiopia and so on. These companies have since grown to majorly generate space products locally, increase space awareness and inspire the birth of other space companies among other advantages leading to the country's development.

Limitations of Study

- Lack of dedicated space journals in Africa that can enforce quality assurance for all earth observation research literature therefore analysis and excellence of the sources used in this review can not be fully validated.
- The study only considered farms, companies and personnel all primarily based in the country's central region excluding all other regions that might have provided a slight modification of the results collected from the field qualitatively.
- While the study identifies gaps in policy and institutional use of satellite data, it focuses on the farmers and does not deeply evaluate the implementation challenges faced by affected Ugandan governmental and non-governmental stakeholders. Future research could incorporate key informant interviews from policy-makers and data providers.
- The study did not include pilot testing of proposed services in Uganda. Technical feasibility is inferred from validation literature rather than demonstrated empirically. Future work should include pilot validation before full-scale deployment

Table 8: Satellite- based solutions mapping to agricultural models

Challenge	Solution
Disasters (droughts, floods, pests and diseases	Early disaster warning and prediction informs decision making and maximizing preparedness. Damage assessment for efficient relief.
Land degradation	Soil mapping and fertility evaluation to identify land suitabili
Limited access to credit	Historical agricultural performance assessment and forecasting supporting credit worthiness. Time series prediction.
Low crop yields	Crop health monitoring Regional yield prediction for informed post harvest handling.

Recommendations

Policy

From the discussion above, the Ugandan government through the Ministries of Agriculture and Science needs to create policies supporting adoption of agricultural technologies and satellite applications. Lessons can be drawn from other African countries like Kenya, SouthAfrica, Nigeria, Angola among others where successful policy integration that has facilitated satellite data utilization in agriculture. The gap between capability and impact is largely a gap in legal certainty. Uganda cannot move from consuming space services to producing them on ambition alone however policies and frameworks are necessary to let public and private capital share risk with confidence. Finally, newly formulated space policies should be explicitly structured to promote the development of Uganda's domestic private sector by eliminating burdensome licensing procedures, reducing prohibitive fees, and removing unnecessary regulatory barriers that hinder the establishment and growth of local enterprises.

Research & Innovation

We recommend the Space and Aeronautics Bureau to form a dedicated research department and implement a rigorous phased annual strategic plan to support local efforts among all interested stakeholders of the country. Research in remote sensing applications for agriculture should be maintained and strengthened through partnerships with local universities, agricultural research institutes, and the private sector. There is currently rapid technological advancement in African space agriculture as seen from other countries. For example, Kenya's precision agriculture advancement through their recent Taifa-1 satellite provides 16-meter resolution panchromatic and 32-meter multispectral imagery specifically designed for crop condition monitoring and yield estimation highlighting the effect of cutting edge technology innovation in earth observation for agriculture (Digital Earth Africa, 2021) . All research efforts carried out need to contextualize satellite technologies to Uganda's unique agro-ecological zones while considering socio-economic factors to generate locally relevant knowledge and innovations.

Capacity building

We propose a muti-faceted approach for space capacity building in Uganda. Firstly we suggest a compulsory incorporation of remote sensing technology into Uganda's public agricultural systems at national level as enforced by the Ministry of Agriculture. This will ensure all agricultural field officers in the country are trained to interpret, use satellite data and geospatial tools in a structured impactful manner. Secondly, local universities can be supported by the government to grow training efforts by sponsoring skills upgrade of educators in other developed countries for benchmarking purposes. These highly trained educators are key drivers of capacity building for the future generations upon return to the country as they transmit the skills learned. Thirdly, we encourage collaboration between academia and industry to support satellite based agriculture of professionals. Academia should establish continuous professional development programs through in-person workshops and online tutorials leveraging partnerships with international organizations to enhance technical skills such as space-derived data management, space entrepreneurship skills and policy among others for different industry sectors.

Collaboration and Partnerships

Multi-stakeholder collaboration is essential for scaling satellite-driven agricultural solutions in a country's growth as seen from other African countries such as Nigeria, South Africa, Angola among others partner with European states receiving over C100 million investment for agricultural applications using satellite technology (360Mozambique, 2024), (European External Action Service (EEAS), 2018), (Directorate-General for International Partnerships, European Commission, 2025). This has increased the ability to cover the cost of starting up space companies in these countries. The African Space Agency's funding strategy is also a great example of continental-level resource mobilization to its various member states to implement earth observation projects for food security. We recommend Uganda to partner with other African government agencies and international organizations for skills acquisition, acceleration of technology transfer, driving resource mobilization and enhancement of market entry.

Custom affordable packages

Following up from the discussions before from the previous section and survey results from the small holder farmers, we recommend subsidization of prices paid for satellite data and satellite agricultural based technologies by government and private sector service providers to ensure accessibility for low-income farmers. Local EO service providers should develop affordable and customized satellite service packages tailored to the needs of small holder farmers in Uganda. These packages must include the relevant fundamental features such as access to processed satellite data training on data interpretation, and personalized agricultural advice delivered via SMS or mobile apps to increase accessibility.

National Remote Sensing Repository

A national online Earth Observation (EO) data hub is proposed for Uganda to improve access to and sharing of real-time satellite data among researchers, policymakers, and the private sector. The platform would be cost-effective, user-friendly, scalable, and mobile-enabled, supporting applications such as climate monitoring, crop health assessment, and land-use analysis. The concept draws on regional models such as Esoko in Ghana and similar systems in Kenya. Implementation could leverage infrastructure from National Information Technology Authority-Uganda and Makerere University to ensure accessibility and reduced costs. The platform could later support the development of a physical EO data center for training and capacity building in data processing and analysis.

Supplementary technologies for satellite data systems

The aforementioned satellite technologies can be supported by other enabling technologies such as IoT, cloud computing and AI that enhance the utility of satellite data in agriculture. The ability to come up with insightful analytics depends on the ability to obtain reliable data. Quite often, the utmost precision is achieved by cross-validating the data from ground probes with satellite imagery data. Through IoT technology, ground probes are able to deliver real-time ground-level data that supplement satellite observations, improving spatial and temporal accuracy (EOS Data Analytics, 2023). Cloud computing offers the infrastructure required to store, manage, and process the large volumes of remote sensing data, enabling advanced, accurate, reliable analytics while Artificial Intelligence through evolving machine learning (ML) predictive models has transformed satellite imagery management, by analyzing vast amounts of data from the sensors and satellites (Juan *et al.*, 2025). These technologies when supplemented with satellite systems have enormous potential to accelerate precision agriculture in Uganda .

CONCLUSION

The integration of satellite applications into Uganda's agricultural sector presents a transformative opportunity to enhance food security, productivity, and climate resilience while advancing its position in digital agriculture. This study highlights both the potential of space-based data and the structural challenges to adoption, noting that Uganda is in the early stages of developing a space governance framework with growing interest from farmers and experts despite constraints in access, infrastructure, and technical capacity. Addressing these gaps requires coordinated, multi-stakeholder engagement across government, industry, academia, and the agricultural community to ensure effective and equitable implementation, thereby enabling sustainable agricultural development through the alignment of technology, policy, and human capital.

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