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Drones' Uses in Ethiopian Agriculture and Their Role in Innovating Future Farming

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Abstract

Drones are an emerging technology currently utilized in agriculture for various applications. However, drone adoption in Ethiopian agriculture remains limited, despite the sector's vital role in the country's economy. This study uniquely aims to identify the key factors driving the use of drone technology and the challenges hindering its widespread adoption in Ethiopia. The research employed focus group surveys for data collection. Questionnaires were created and distributed to 376 individuals working in organizations involved in drone-related activities, yielding 280 responses. The study highlights four main factors that emphasize the urgent need to deploy agricultural drones in Ethiopia: the irrigated wheat initiative, the Ethiopian Green Legacy, and the control of locusts and Tsetse flies. Additionally, the research uncovers several major challenges to drone adoption, including limited skills and knowledge among operators, lack of awareness, high initial costs, the absence of a drone-as-a-service business model, regulatory issues, small-scale farming practices, and the lack of commercial farming. It is essential to develop policies and strategies that promote large-scale commercial farming, tailored drone operation and maintenance training, increased awareness of drone technology and regulations, and the promotion of drones as a service to maximize the benefits of drone technology in Ethiopian agriculture.

Keywords: Ethiopia, Drone, Wheat initiative, Green legacy, Locust, Tsetse

1. Introduction

Agriculture plays a crucial role in the Ethiopian economy, accounting for 45 percent of the country's GDP, providing 80 percent of jobs, and generating the highest export earnings (Alemu et al., 2010; Tamene et al., 2021; Anteneh & Asrat, 2020). Despite this substantial contribution, there remains significant untapped potential and opportunities for growth within Ethiopia's agricultural sector. Most farming is done by small-scale farmers who grow crops like wheat, teff, corn, sesame, barley, fruits, and various horticultural products (Anteneh & Asrat, 2020; Tadesse et al., 2022). Additionally, the sector faces numerous challenges that hinder its development and the well-being of the population. These issues are diverse and interconnected, leading to problems such as low productivity caused by traditional farming methods, small landholdings, limited access to fertilizers, and a lack of modern agricultural technologies (Anteneh & Asrat, 2020; Tadesse et al., 2022).

In other parts of the world, agriculture has seen many innovations that involve crop rotation and advancement in farming practices such as the green revolution which consists of the use of breeding technology and man-made fertilizers to improve agricultural productivity while maintaining environmental standards (King, **2017**; Gebbers & Adamchuk,**2010**; Walter et al., **2017**). The sector also adopted technologies that reduce world-growing food insecurity and the impact of agriculture practices on the environment. Precision agriculture technology that emerged in the early 1990s became successful in resource optimization. It utilizes targeted treatments at the right place and time using information and communication technologies within the farming practice (Gebbers & Adamchuk,**2010**;Walter et al. et al., **2017**). This technology uses smart devices such as drones and robotics to collect big data that helps farmers make timely decisions (Gebbers & Adamchuk,**2010**; Walter et al., **2017**). The adoption of precision agriculture in Ethiopian agriculture is still in the infant stage and the Ethiopian farmers have not maximized its benefits.

Smart devices such as drones in digital farming are commonly used for many purposes that include soil sampling and fertilizing, pesticide spraying, animal population surveillance, real-time imagery, and sensor data collection from farm fields. This minimizes the need for a farmer's physical presence through the fields to observe and control the infrastructures, sowing by enabling smart and precision agriculture (Kitchenham, **2009**; Paul, **2023**). Drones enable farmers to make immediate and informed decisions by providing real-time data about crops. For instance, farmers can monitor vast plots of land to track crop health, crop growth, crop distribution, and variables such as temperature and humidity with an efficiency unattainable by human effort. Hence, drone application in agriculture is a pivotal tool for increasing agricultural land productivity and tackling problems arising from population growth and climate change.

Digital farming practice adoption in developing nations like Ethiopia become a hurdle due to the high costs of adopting technology, regulatory framework, infrastructure, and limited knowledge and skills of emerging technologies (Walter et al., **2017**). Unlike industrialized farms that have an opportunity to use emerging technology, small farmers have limited access to those technologies. Similar to capacity issues, regulatory challenges are also another factor that hinders the utilization of this technology in developing nations. Scholars suggest well-defined regulatory frameworks that ensure the realization of the complete capabilities of drones, while concurrently safeguarding the safety and privacy rights of citizens highly important for those nations (Ayamga et al., **2021**). Insuring the ethical use of drones to prevent misuse, as well as maintaining society's privacy infringements will help drone utilization applications. Thus, it is crucial to examine factors affecting Ethiopia's utilization of drones in agriculture, understand their implications, and learn from global experiences.

The objective of this research is to assess drone use in Ethiopian agriculture and explore factors that push to integrate drones within Ethiopian farming sectors and hindering parameters for their utilization. This examination intends to shed light on the difficulties encountered in Ethiopia and to evaluate the repercussions of minimal usage on the agricultural industry. Through the investigation of diverse agricultural environments, we aim to recommend future policies, encourage technological innovation, and fully leverage the capabilities of drones to revolutionize agricultural practices in Ethiopia.

2. Research Questions

This research aims to address the following questions through a detailed analysis of survey data regarding the growing need for agricultural drones and their challenges in Ethiopian agriculture, as well as examining Ethiopia's experience with agrarian drone technology. The primary goals of this study will be achieved by providing solutions to the research questions. The four core questions guiding this research are as follows:

1. What are the drivers of drone technology adoption in Ethiopia?
2. How prevailing is an agricultural drone in Ethiopia?
3. What are the existing drone regulations in Ethiopia?
4. What factors hinder the use of agricultural drones in Ethiopia?

3. Method and Materials

3.1.Data collection method

Data were collected using Google Forms and a paper survey to reach more individuals working in organizations that utilize drones, provide drone training, promote drone use, and are directly or indirectly involved with drone technology and agricultural activities in Ethiopia. Google Forms is a survey administration software that helps gather survey responses online by creating a web application. Survey collectors can invite respondents via email, Telegram, or other websites to complete the survey. Participants receive information to access the survey website; they complete the form online and then click the “submit” button once they are finished. A web-based data collection method is a viable research tool due to its low costs, time savings, clean and accurate data collection, access to a large and diverse population, and enhanced experience and anonymity for research participants (Ahern, 2005; Aluja et al., 2007). Online data collection can save up to 80% of costs compared to other methods, such as paper surveys. Lower data collection costs are one of the main advantages of online methods (Granello & Wheaton, 2011; Lefever et al., 2007; Ward, 2014). These savings are valuable because they allow researchers to allocate resources to other projects or areas of interest, promoting broader research (Ward, 2014). However, to reach more individuals who are unable to respond online or do not have access to web services, paper survey techniques were applied. Paper surveys are preferable for physically contacting respondents and provide clarification about any doubts concerning the questions. This method helps obtain responses from more people approached for the survey than web-based services. Utilizing both techniques, a total of 376 individuals presumed to be employed in organizations familiar with drones were contacted via email, Telegram messages, or in person. The response rate was 74.5%, resulting in 280 respondents. The majority of respondents were male, aged 31 to 40 years.

3.2. Questionnaire Design and Survey Data Analyzing Methodology

The design of the questionnaire spanned one month, from March 1 to 30, 2025, during which the group met weekly. In the initial phases of the design process, the group gathered and examined existing literature and previous surveys related to the research. Building on this literature review, the group identified the research questions and then developed the questions for the research instrument. After a refinement process, we established a total of 12 items, which included Likert scale, dichotomous, and forced-choice scales. The items were organized according to the three dimensions mentioned earlier (awareness, opinion, and experience) to address the initial research questions effectively. An overview of the questionnaire's structure, including question types and the topics of each item, is presented in Table 1.

The Likert scale items were designed to range from 1 to 5, with 1 indicating the least positive or negative values and 5 representing the most positive or negative values. The choice of a 5-point Likert scale was made because it is widely utilized in social science research to examine human opinion and awareness (Nunnally, 1994). Although the ideal number of options in a Likert-type scale is a matter of debate [Joshi et al, 2015], we selected a 5-point scale to ensure simplicity and clarity of the items (Likert, **1932**; Joshi et al, **2015**). For other questionnaires that require numerical answers, a pie chart was used to analyze survey responses. Pie charts are often employed to show how different categories comprise a whole by illustrating numerical proportions. Furthermore, additional data was scrutinized with an emphasis on critical factors that ensure the validity and reliability of the methodologies recommended in the literature (Cohen,2007). The analysis of the survey data revealed a significant need for agricultural drones, which necessitate the support of government policies. The survey data were analyzed by categorizing key government priority areas, including the Wheat initiative, the Green Legacy initiative, and locust and Tsetse fly control efforts.

Table 1: Questionnaire category, type, and questions

Category	Question type	Questions
Awareness	Likert scale	Q1: Are you aware of drone technology for farming? Q2: How much are you aware of drone regulation in Ethiopia?
	Dichotomous	Q3: Do you know the remote pilot Licensing and Rating requirements for operating a drone? Q4: Do you know the eligibility criteria to own a drone Q5: Do you know what drones do in agriculture? Q6: Do you know any drone service provider companies in Ethiopia?
Expreince	Forced-choice scale	Q7: Please select the statement that best matches your experience with drones
opinion	Likert scale	Q8: How do you view the use of drones in agriculture? Q9: Rate each factors that limit the use of drones in agriculture in Ethiopia? Q10: Rate the extent to which the following agricultural operations in Ethiopia require drone services? Q11: Rate the extent to which the following food and commercial crop farming requires drone service? Q12: Rate the extent to which each of the following factors limits the use of drones in agriculture in Ethiopia.

4. Results

4.1.Survey Respondents' Class and Knowledge About Drone Analysis

Many respondents belong to the 31 to 40 age group, which represents 63%, followed by the 20 to 30 age group at 23%. The remaining respondents are aged 40 and above. Most respondents, comprising 88.6%, are male, while 11.4% are female. A significant portion of the respondents, accounting for 77.1%, hold an MSc or higher, while the rest hold a BSc. The selection of the survey methodology and the initial determination of the population from which to collect data may have encouraged the participation of individuals with higher levels of education. Furthermore, 91.4% of the respondents work in the public sector, including public research institutes, academia, and public organizations, while the remaining respondents work in the private sector and civil society organizations. This is due to the survey being sent to select organizations involved in drone research, public use, and promoting drone technology in Ethiopia. Supporting the preliminary evaluation, a significant number of respondents were aware of drones. Among those who are aware, 68.6% have not used drones for any activities, while 17.1% have used drones for other activities but not for agricultural applications, and 8.6% have utilized drones for agricultural purposes. A limited number of respondents have used drones for various operations, including agriculture, and do not know about drone technology at all, as shown in Figure 1.

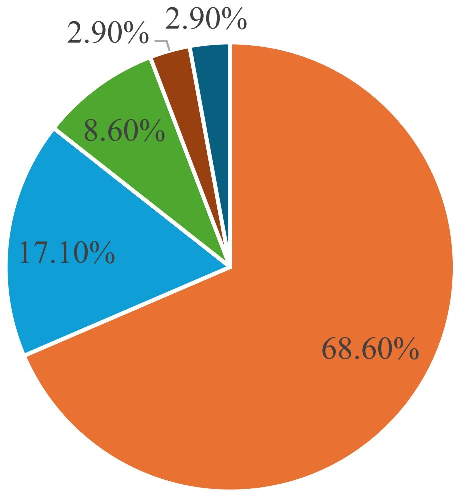

Fig. 1. Survey respondents' experience with drones

4.2.The Growing Need for Agricultural Drones in Ethiopia

As the agricultural sector expands alongside a growing population, there is an increasing demand for advanced technologies, such as agricultural drones and harvesting robots, to address labor shortages and improve efficiency. In response to these challenges and to enhance agricultural productivity, the Ethiopian government has established a Farming Transformation Agency aimed at accelerating the growth and modernization of Ethiopia's agricultural sector (Effa et al., 2023). Additionally, a system has been introduced for small farmers to collaborate in pooling their resources, thus achieving economies of scale in production, marketing, and distribution. This collaborative approach enables farmers to adopt modern agricultural technologies, improve both the quality and quantity of their output, reduce production costs, enhance market access, and receive government support in the form of funding, training, technical assistance, and access to superior seeds and fertilizers. To further this initiative, the government has launched an irrigated wheat program that draws on successful cluster farming models from Taiwan and South Korea (Effa et al., 2023; EIAR, 2020; Shikur, 2022). Additionally, in 2019, Ethiopia initiated a green legacy program to restore degraded lands, improve forest cover, mitigate the effects of climate change, and capitalize on carbon credits (Abebe & Arega, 2023; Lambert & Deyganto, 2024; Monitor, Ethiopian, 2023). As a result, the country has successfully planted billions of trees annually, making this initiative a key government priority overseen by a team led by the Prime Minister (Abebe & Arega, 2023). Furthermore, the Ethiopian government is actively addressing the challenges posed by locusts (Ayana, 2023; Zhang el al., 2019) and Tsetse flies (Gebre et al., 2022; Desta et al., 2013; Denu et al., 2012) in the agricultural sector. Recently, desert locusts have invaded extensive areas, consuming vast amounts of vegetation in the eastern and southeastern regions, with expectations of continued impact in the coming years (Ayana, 2023; Zhang el al., 2019). Likewise, Tsetse flies adversely affect agriculture by harming livestock and humans through bloodsucking and the transmission of serious diseases (Gebre et al., 2022; Desta et al., 2013; Denu et al., 2012). The recent invasion of desert locusts threatens to undermine the gains made in agricultural productivity, while Tsetse flies pose a significant risk to livestock health and, by extension, food security. The government's active response to these threats is crucial, as effective pest management strategies will be essential for safeguarding crops and livestock. Furthermore, significant advancements in emerging technologies have driven the nation to adopt advanced agricultural technologies. As depicted in Figure 2, a considerable majority of respondents (over 65%) demonstrate a strong interest in the application of drones in agricultural practices in Ethiopia, with only a minor proportion remaining neutral. The positive perspective of respondents aligns with various government initiatives that promote the use of drones in the agricultural sector, as well as a growing awareness within contemporary society regarding modern technologies.

Hence, as awareness of these technologies increases, it is likely that more farmers will be willing to embrace them, leading to enhanced productivity and efficiency.

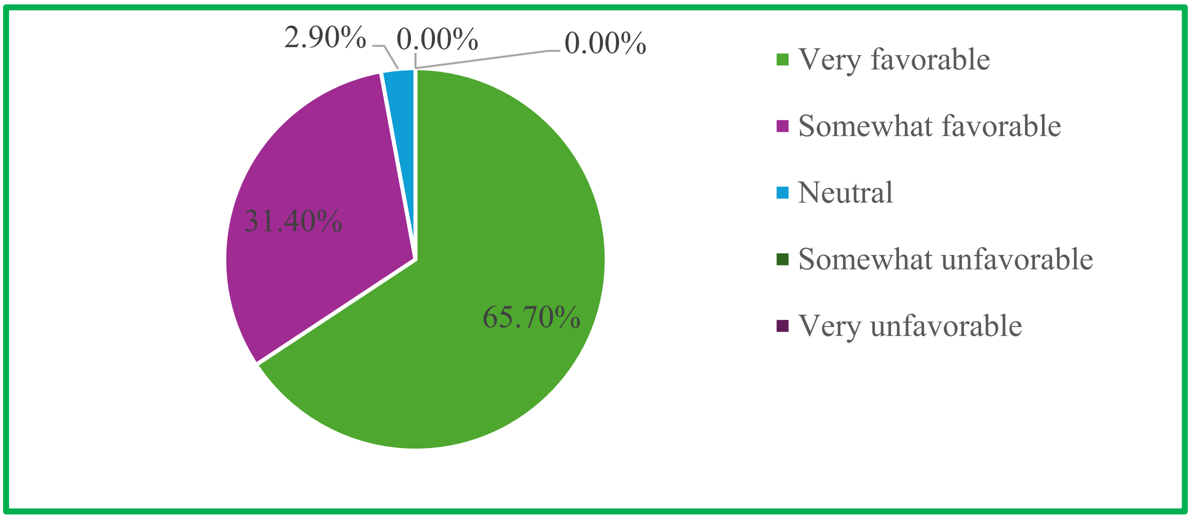

Fig. 2. The interest of survey participants in the utilization of drones in the Ethiopian agriculture sector

4.2.1. Ethiopia Irrigated Wheat Initiative

Ethiopia has recently launched an irrigated wheat initiative utilizing a cluster farming strategy to address significant trade deficits in agricultural products and food shortages resulting from rapid population growth. This cluster farming method aims to consolidate farmers with neighboring plots to cultivate the same crop across their fields, thereby enhancing resource distribution and utilization (Ethiopian agricultural transformation agency, **2024**; Degefu et al., **2024**; Dureti et al., **2023**). This collaborative approach necessitates collective decision-making regarding shared resources, including the use of agricultural drones. Furthermore, Ethiopia intends to extend this cluster farming model, initially applied to irrigated wheat, to other crops. Such practices will enable farmers to leverage modern agricultural technologies, such as drones and the Internet of Things (IoT), which are not economically viable in fragmented farmland settings (Ethiopian agricultural transformation agency, **2024**; Degefu et al., **2024**; Dureti et al., **2023**). The initiative is spearheaded by the Ethiopian Institute of Agricultural Research (EIAR) and is supported by the Ministry of Agriculture (MoA) and the Office of the Prime Minister. EIAR has been designated as the project coordinator, responsible for providing oversight and technical assistance to ensure successful implementation. To bolster the irrigated wheat initiative, the government has made continuous efforts to supply essential inputs, including fertilizers, wheat varieties, agrochemicals, financing, and modern agricultural technologies and machinery ((Walter et al., **2017**; EIAR, **2020**). This financial support has encouraged various stakeholders to engage in irrigated wheat production and adopt technologies like agricultural drones to enhance productivity. In Figure 3, we illustrated the percentages of responses to Likert scale items of major food and commercial crops (wheat, coffee, cotton, fruit, sesame and others) related to the opinion on the need for agricultural drones prior. The light blue and deep blue segments denote the two extreme positions: high and low levels of opinion, respectively. The largest light blue and brown segment, which encompasses the wto highst scale values (i.e., 5 and 4) respondntas opinion indicates need for agricultural drone for application in major crop under the study. As depicted in Figure 3, the application of drone technology in wheat farming is deemed a priority area in Ethiopia, likely due to wheat being the predominant cereal crop cultivated across many regions and the recent government initiative aimed at achieving food self-sufficiency, which has influenced the responses of survey participants. Furthermore, it was observed that a majority of respondents identified drone technology as a priority not only in wheat farming but also in the cultivation of coffee, fruits, cotton, sesame, and other cereal crops. Conversely, a minority of respondents expressed that drone technology holds the least importance in wheat, coffee, and other cereal farming. Traditional agricultural practices in Ethiopia predominantly rely on human labor for the cultivation of wheat, coffee, and other cereals, leading some respondents to express concerns that the introduction of new technologies might result in job losses. In contrast, for crops such as fruits, cotton, and sesame, respondents appear to recognize that the inherent characteristics of these agricultural products necessitate the adoption of new technologies to address the various challenges associated with labor-intensive operations.

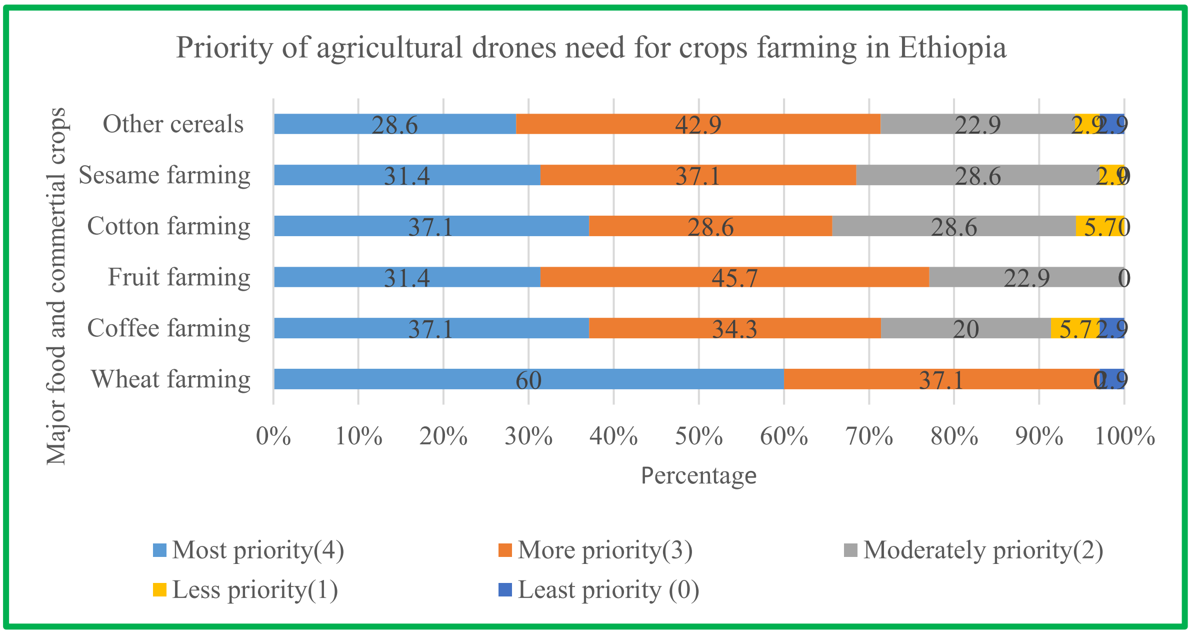

Fig. 3. Drones need in various agricultural product farming in Ethiopia

4.2.2. Locust impact

The desert locust is a highly mobile pest worldwide, feeding on large quantities of green vegetation, including crops, grazing lands, and trees, and causing significant deterioration in food security across Ethiopia and other East African countries (Ayana, 2023; Zhang et al., **2019**). According to FAO locust watch in 2019-2021, the worst desert locust outbreak in 25 years has caused significant pasture losses across East Africa, mainly in agro-pastoral areas of eastern Ethiopia, central Eritrea, Djibouti Somalia, and northern Kenya (FAO, **2024**). Ethiopia experienced two insertions of desert locusts in 2020 covering a large area of land. Locusts become a natural problem in East Africa and their damage to agricultural products is high. It covers large land once it starts its movement each year and the impact it generates on agricultural output is too high. This results in economic loss to the farmer and creates disasters. Ethiopians mostly use traditional methods such as noise making or smoking as a control or prevention method, backpack spraying, and burying of the locusts to protect their agricultural farms from locust inversion and it is not efficient. The government sometimes employs an aircraft for spraying insecticides to eliminate the locusts (Showler et al., **2021**). However, the movements of the locusts cover large areas, and the usage of aircraft is not cost-effective. Figure 4 illustrates the demand for drones in various agricultural sectors, which encompass crop health assessment, farmland mapping, spraying applications, control of locusts and Tsetse flies, as well as planting and seeding tasks. All survey participants (100%) indicated a strong necessity for drones in locust control, followed closely by spraying applications (97.1%), Tsetse fly control (94%), farmland mapping (91.4%), crop health assessment (88.5%), and planting and seeding (57%). The response indicates a high need for drones in locust control since the impact of such pest invention on farmland is recognized and known by many respondents. Respondents perceive the adoption of drones for planting and seeding in Ethiopia as relatively unimportant, primarily due to the government's reliance on traditional human-based seeding and planting methods, coupled with a predominantly rural population.

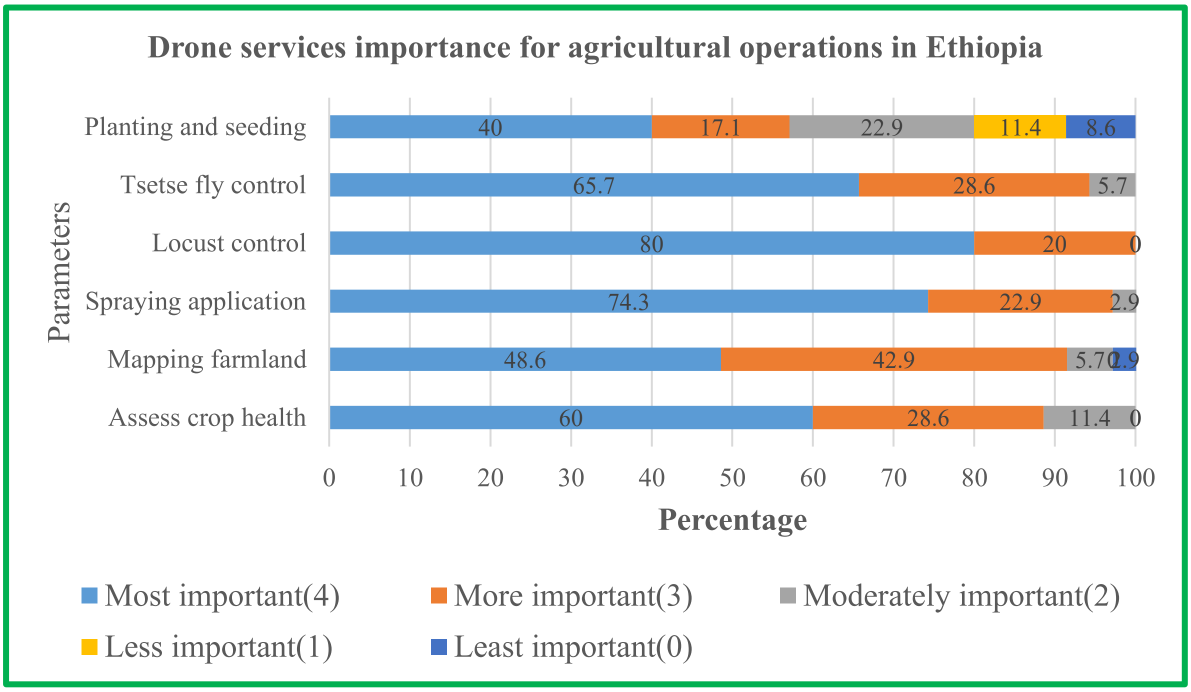

Fig. 4. Drone Service needs in different agricultural support in Ethiopia

4.2.3. Tsetse fly impact

The Tsetse fly is endemic to Africa and serves as a vector for a parasite that poses significant health risks to humans and is fatal to livestock. It is responsible for the transmission of African animal trypanosomosis (AAT), a critical disease that hampers livestock productivity in sub-Saharan Africa (Gebre et al., **2022**;Desta et al., **2013**;Denu et al., **2012**). Livestock plays a vital role agricultural sector, contributing 45% to the agricultural GDP (Asresi & Seifu, **2015**; Metaferia et al., **2011**). As illustrated in Figure 4, the survey participants replied, that the use of drones for Tsetse fly control ranks among the top three areas where the urgent application of this technology is necessary. For over five decades, various methods for controlling tsetse fly populations have been implemented in Ethiopia, primarily relying on insecticides for suppression or eradication. One notable approach is the sterile insect technique (SIT), which employs a genetic manipulation strategy akin to "birth control." This method entails the mass-rearing of the target tsetse species, sterilization of male flies, and the subsequent release of these sterile males into the wild, leading to infertility among mated females (Vreysen et al., **2013**). The implementation of this technique necessitates the use of aircraft or drones for the distribution of sterilized males. However, the process of sex sorting after the flies emerge from pupae, along with the complexities of transportation and handling, can hinder its effectiveness. Consequently, agricultural drones are viewed as a promising future application in supporting of the SIT method, with the International Atomic Energy Agency (IAEA) advocating for their use to enhance the release of sterilized tsetse flies. The demand for drones in this context is anticipated to increase in the near future.

4.2.4. **Green Legacy Initiative**

In Ethiopia, forests play a significant role in providing social or cultural benefits, maintaining an environment, and preventing climate change (Monitor, Ethiopian, **2023**). Deforestation and forest degradation increased in past decades due to population growth and significant progress has not been made in reversing the situation. It is one of the pressing environmental issues having immediate consequences in the lives and livelihood of millions of people, particularly in rural communities leading to increased fuel scarcity, reduced supply of fodder, and leaf-litter manure. Most recently, Ethiopia launched a mass tree planting program called the Green Legacy Initiative (GLI) in 2019 to restore degraded lands, increase forest cover, and reduce the impact of climate change. Ethiopia targeted planting 20 billion seedlings in the first phase of GLI (2019 to 2023) but Ethiopia planted 25 billion forests, agroforests, and fruit seedlings (Abebe & Arega, **2023**; Lambert & Deyganto, **2024**;Monitor, Ethiopian, **2023**). The nation has set a mission of planting seedlings in cities and rural areas to improve the benefit of forests for the country's social and ecological goals and realize Ethiopia's prosperity. This plan and ambition to cover land with more seeding must be supported with modern technologies, especially in an area unsuitable for planting by human force. Drone-based seeding is modern technology that uses drones to plant seeds to bring greenery back to landscapes that have steep slopes, degraded landscapes, and erosion-prone areas. It is an alternative to ground-based seeding methods that include planting by hand or tractor seeding. The Ethiopian government has great ambition for utilizing artificial intelligence technology and supporting GLI with technology outcomes such as seed bombing which highlights the significance of safeguarding and restoring terrestrial ecosystems. Green legacy initiatives that require drones for planting and seeding applications, as well as for mapping areas covered by forests and barren lands, and in rare instances for watering plants, received lower scores from survey respondents compared to other factors, as illustrated in Figure 4. The underlying principle of the green legacy initiative is to inspire society to safeguard the environment and restore barren land through human-driven seeding and planting strategies. Given that much of Ethiopia's topography is accessible to people, the necessity for drones in this context is not particularly significant.

4.3.Challenges with the Use of Drones in Ethiopian Agriculture

Ethiopia faces significant challenges in adopting agricultural drone technology, despite the pressing need for it. Key obstacles include the high initial costs associated with purchasing drones, a scarcity of drone-as-a-service businesses tailored for agricultural use, and a lack of skills and knowledge necessary for the operation and maintenance of these devices. Additionally, there is limited awareness of drone-related technologies, regulatory issues, traditional farming practices that involve land division for various crops, and a prevalence of small-scale farming. Although the country's strategies aim to promote modern technologies to engage educated youth in rural areas, the absence of initial capital and technical support hampers widespread adoption. For small-scale farmers, utilizing drones presents a more economical option for gathering data than relying on human force and manned aircraft or satellite imagery. Drones enable farmers to assess crop health and nutritional requirements, facilitating informed decision-making that may not be easily achievable through traditional ground-level scouting. This may motivate farmers to incorporate drone technology to enhance productivity on agricultural lands and bolster food security in near future.

4.3.1. Cost of Drone and Drone Service Business

The expense associated with drones poses significant challenges for small farmers seeking to integrate drone technology into their agricultural practices. As illustrated in Figure 4, both the high cost of drones and the lack of a drone-as-a-service (DaaS) model are primary obstacles to the adoption of drone technology within the Ethiopian agricultural sector. According to survey results illustratued in Figure 5, 77% and 71% of respondents identified the cost of drones and the absence of DaaS, respectively, as key barriers to drone utilization in Ethiopian farming. The notion of drone-as-a-service is still relatively unknown in Ethiopia, rendering it an impractical business model for small-scale farmers at this time. Notably, even larger enterprises are opting for drone services rather than investing in their drones, primarily due to the high costs associated with commercial-grade drones or other reasons. This trend is expected to drive the growth of the Drones-as-a-Service (DaaS) market, enabling businesses to manage their financial resources more effectively (Nwaogu, **2024**). Therefore, promoting such service-oriented enterprises in rural agricultural regions could lead to job creation and increased agricultural productivity, ultimately enhancing the financial returns for farmers.

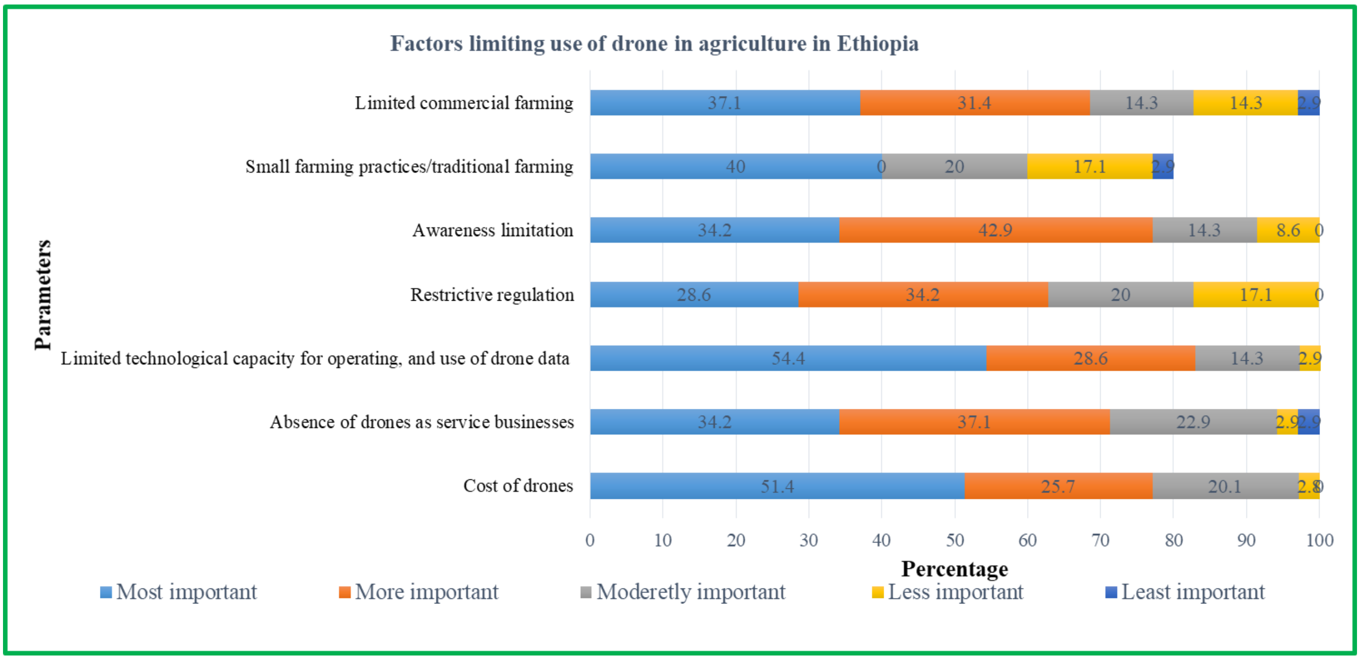

Fig. 5. Factors limiting farming drone use in Ethiopia

4.3.2. Limited Skills and Knowledge of Drone Operator and Utilization of Drone Data

A significant majority of respondents (82.8%) indicated that the limited technological capacity of drone operators and the utilization of drone data are the most critical factors influencing the adoption of drones in Ethiopia's agricultural sector as seen in Figure 5. There is an urgent need to establish educational and training programs focused on drone operation, as well as to create facilities dedicated to the maintenance, repair, and overhaul of drones to address this issue. Effective drone operation requires a blend of skills and experience in equipment management, image capture, and data editing to achieve specific operational objectives. Such proficiency is vital for producing high-quality outcomes that improve productivity and yield economic benefits. In addition to conventional in-person training for drone operation, the workforce would significantly benefit from simulation-based training, which encompasses virtual reality, augmented reality (AR), and mixed reality experiences. By offering practical flying training in simulated environments that closely mimic actual operational sites, workers can refine their drone flying abilities and promote safer operational practices. This approach facilitates effective training while minimizing exposure to real-world risks. Moreover, drone flight simulations can be employed to teach the workforce effective data collection methods, the conversion of collected data into 3D models, and appropriate responses to technical failures or emergencies. Specifically, the skills and capabilities of drone operators can be greatly enhanced through the establishment of dedicated drone training facilities and proficiency evaluations for operators(Nwaogu, **2024**; Moon & Ock, **2023**). In this services, government involvement is minimal, and only a few small and micro enterprises are engaged in providing such services. To address this challenges, it is advisable for higher education institutions to initiate practical drone training programs, as they generally possess the necessary facilities and expertise. A designated drone training facility will enable operators to acquire the essential knowledge, experience, and skills required for effective drone operation. Proficiency assessments and upon successful completion of these evaluations issuing certificates or licenses to the operators will increase expertise within the market. The Ethiopian Civil Aviation (ECA) an authority controlling drone related regulation may grant a certificate or license contingent upon the successful completion of training at an accredited institution and passing the requisite examination (Ethiopian Civil Aviation Authority (ECAA), **2023**). It is crucial to verify and confirm the competence of operators before assigning them specialized tasks to ensure that operations are performed safely and in accordance with legal regulations.

4.3.3. The Regulatory Landscape for Airspace Security in Ethiopia

The regulation of drone-related issues is perceived as optimal by survey respondents, with 62.8% indicating that Ethiopian drone regulations are restrictive for agricultural use, as illustrated in Figure 5. Moreover, approximately 77.1% of participants reported that a lack of awareness about drone technology has negatively impacted its utilization. In April 2023, Ethiopia implemented regulations governing the operation of unmanned aerial vehicles (UAVs) to address potential risks associated with their use in society. These regulations are outlined in Part 22 of the Ethiopian Standards for Remotely Piloted Aircraft Systems (RPAS) (Ethiopian Civil Aviation Authority (ECAA), 2023). According to the Ethiopian Civil Aviation Authority (ECAA), individuals or entities eligible to own or operate RPAS must be Ethiopian citizens or residents, registered companies in Ethiopia, or possess legal documentation allowing residency in the country, with a minimum age requirement of 18 years. The operation of drones in Ethiopia is governed by RPAS standards, which require obtaining security clearance from the Information Network Security Administration (INSA) and/or the National Intelligence and Security Service (NISS) before the importation, manufacturing, or ownership of drones. After securing the necessary security clearance, UAVs must be classified and registered with the ECAA to obtain an unmanned aircraft operator's permit (UAOP) for operation. UAV operations in Ethiopia are strictly prohibited without prior approval from the ECAA and security clearance from INSA and NISS. Additionally, RPAS pilots or instructors must acquire certification from the ECAA or an accredited international institution, in accordance with the established operational requirements. The rigorous processes for approval and certification regarding security clearance, registration, operation, and pilot licensing impose significant restrictions on the use of drones in agriculture and other general applications within Ethiopia. Moreover, RPAS regulations also impose restrictions on payloads exceeding specified weights and necessitate approval for the application of chemicals, thereby limiting spraying and pod planting activities. As illustrated in Figure 6, 14.3% of respondents from each category reported being very aware or somewhat unaware of Ethiopian drone regulations, while 8.6% indicated they were completely unaware of these regulations. Approximately 34.3% of survey participants remained neutral, and 28.6% stated they were somewhat aware of the regulations. It is particularly concerning that these communities remain uninformed about the regulations, especially considering that the data was gathered from institutions believed to be engaged in the drone sector and from experts knowledgeable about drone technologies. Although the regulation was recently enacted, it must be effectively communicated to the public. This lack of awareness has adversely affected drone utilization in the country, impacting both end users and service providers. This suggests that only a limited portion of the community is familiar with the regulations.

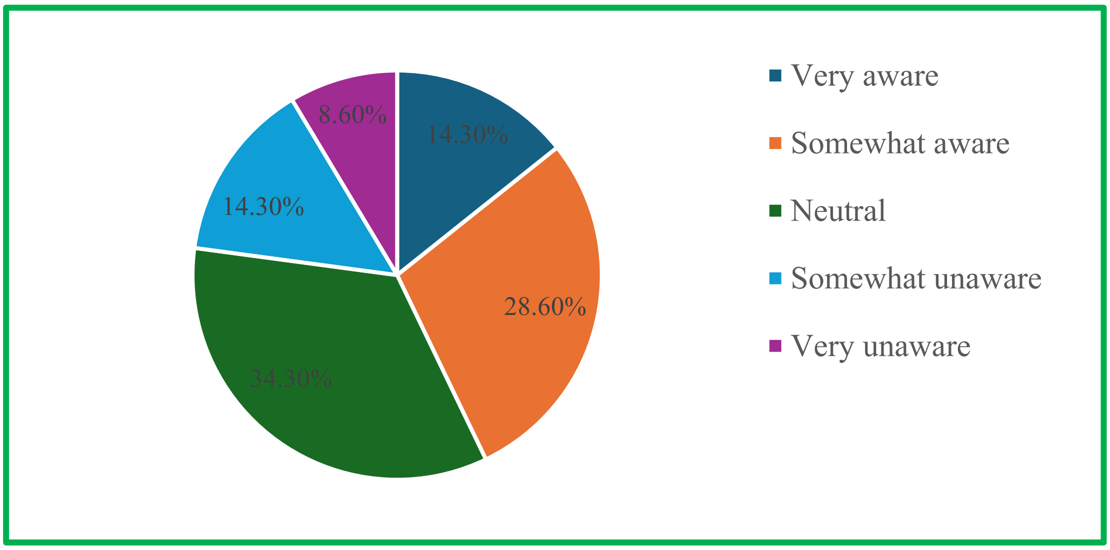

Fig. 6. Drone regulation awareness in Ethiopia

4.3.4. Small Land-Based Farming and Limited Commercial Farming

Small land-based farming practices by rural farmers are also contributing factors to the utilization of drones in Ethiopia's agricultural sector, accounting for 60% of survey respondents. Additionally, 68.5% of the respondents mentioned limited large commercial farming in Ethiopia impacted the deployment and distribution of agrarian drones, as illustrated in Figure 5. This situation can be attributed to the fact that approximately 95% of Ethiopian agriculture has historically relied on smallholder farmers, primarily dependent on rainfall. This practice limits the utilization of up-to-date technologies such as digital farming that utilize devices such as drones for data collection. Farmlands of small farmers are also small and, in most cases, fragmented and located in different areas, which diminishes the efficiency and benefits from economies of scale. The financial burden associated with adopting drone technology poses a significant challenge for small-scale farmers. In contrast, the investment in advanced technologies by large commercial farming enterprises in Ethiopia is also minimal when compared to the vast agricultural land available for diverse crop production. Furthermore, the limited regulatory framework and practices discourage large commercial farmers from collaborating with and supporting small-scale farmers in the adoption of these technologies.

5. Conclusion

The study examined drone adoption in the Ethiopian agriculture sector by analyzing government reforms, pilot projects, and challenges to integrating it, and recommended policy related to its adoption. Drones are recognized as essential tools in Ethiopian agriculture to support major government initiatives, including irrigated wheat production, locust and tsetse fly control, and the Green Legacy initiative. The findings revealed a 100% priority for drones in locust control efforts and over 90% priority in areas such as irrigated wheat programs, tsetse fly management, farmland mapping, crop health monitoring, and drone-assisted planting to support reforestation and environmental efforts. Despite the high demand, several barriers are hindering widespread drone adoption. These include high acquisition and operational costs, a limited number of drone service providers, a shortage of trained drone operators and technicians, regulatory constraints related to airspace security, the dominance of small-scale farming practices, and the limited presence of large-scale commercial agriculture. To address these challenges, the study recommends strategic interventions such as promoting and supporting large-scale commercial farming to increase the feasibility of drone applications, developing targeted training programs for drone operation, maintenance, and agronomic data interpretation, raising awareness of drone technologies among farmers, stakeholders, and policymakers, improving the regulatory framework to balance airspace security with agricultural innovation, and encouraging the development of drone-as-a-service business models to make drone access more affordable and scalable. Implementing these policies can help Ethiopia harness drone technology to transform its agricultural landscape, increase productivity, and promote environmental sustainability.

6. References

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