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Status and Opportunities for Animal Traction Technology in Eastern Uganda

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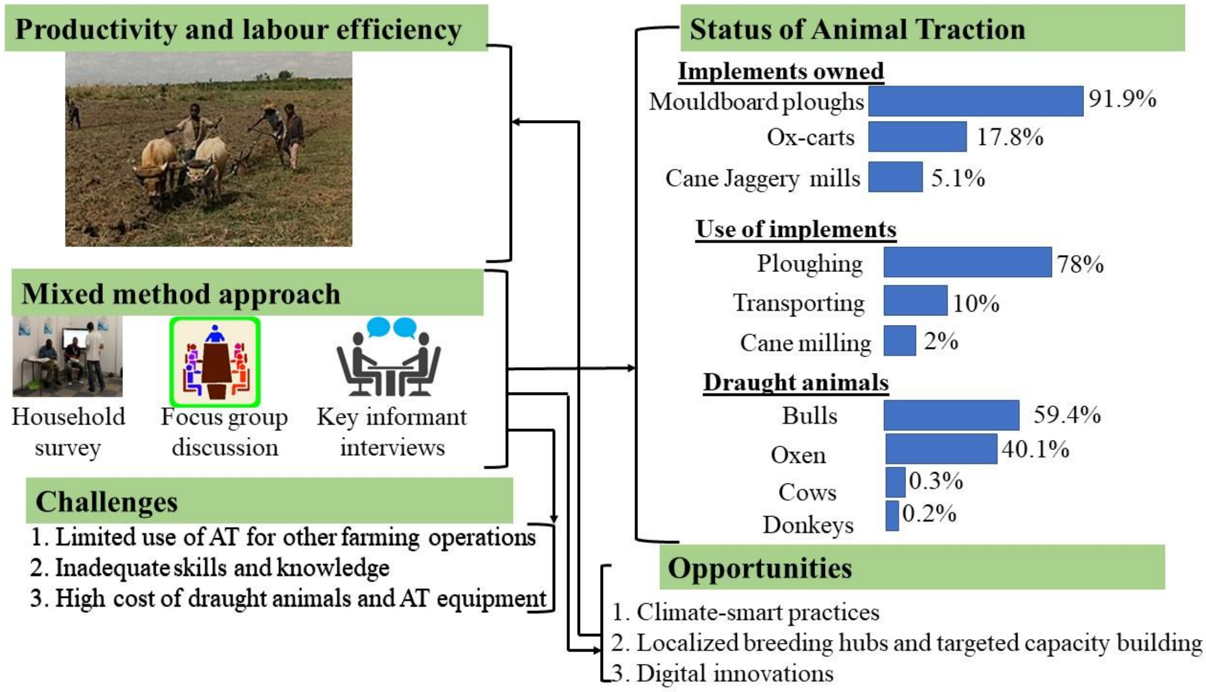
Abstract Animal Traction (AT) technology, is a key driver in improving productivity and labour efficiency in sub-Saharan Africa, including Uganda for smallholder farmers. This study assessed the status, challenges, and opportunities for Animal Traction Technology (ATT) in the Busoga sub-region of Uganda. A mixed-methods approach involving household surveys, key informant interviews, and focus group discussions was used. The study revealed that the main AT implements owned were mouldboard ploughs, ox-carts and cane jaggery mills at 91.9%, 17.8%, and 5.1% respectively. The use of these implements was at 78% ploughing, 10% transportation, and 2% cane jaggery milling. The draught animals used were bulls (59.4%), oxen (40.1%), donkeys (0.2%) and cows (0.3%). The average cost of an AT package (2 bulls, 1 plough, 1 cart, 1 plough yoke, 1 transport yoke and 4 halters) was UGX 4,795,000 (USD 1,370). The highlighted challenges to AT use were limited use of AT for other farming operations, inadequate knowledge and skills, inadequate repair and maintenance services, high cost of draught animals and AT equipment, and inappropriate care and management of draught animals, among others. Despite these barriers, there is potential for revitalizing ATT through climate-smart practices, localized breeding hubs, value chain strengthening, digital innovation, and targeted capacity building. This calls for integrated policy support and investment in decentralized ATT service models to enhance productivity, resilience, and inclusivity in Uganda's agricultural sector. The research contributes to sustainable mechanization by repositioning ATT as a viable, adaptable, and affordable technology for smallholder farmer transformation in Sub-Saharan Africa.

Graphical Abstract



Keywords Animal Traction, Smallholder, Draught Animal, Mechanization, Busoga Sub-Region

1. Introduction

Agricultural mechanization in the form of Animal Traction (AT) remains a critical driver of productivity and labour efficiency in smallholder farming systems, particularly in developing countries serving more than 50 million households worldwide [1]. Animal Traction Technology (ATT) involves the use of draught animals such as oxen, donkeys, horses, and buffaloes to pull agricultural implements such as ploughs, planters, weeders, sprayers, and carts. ATT offers a cost-effective, accessible, and environmentally sustainable alternative to mechanized agriculture, particularly in regions where financial, infrastructural, and ecological constraints limit the use of tractors and other motorized equipment [2]. Further, it is the most suitable technology for smallholder farmers with limited landholdings, particularly for ploughing fields and transporting goods. It also reduces labour demands, facilitates access to the market, and supports more sustainable land management practices in areas where mechanization remains either unaffordable or impractical [2-4].

As with the global trend, the use of ATT remains indispensable in Africa and Asia for farming tasks such as ploughing, planting, weeding, transportation, and water hauling [5]. This is attributed to the enhanced efficiency, adaptability, and usability of ATT in low-input farming systems, owing to technological advancements in implements such as ploughs, harnessing systems, and multi-purpose carts [6].

In Uganda, the situation is no different, with AT use amounting to 10% compared to other mechanization options, such as tractors, which are at 1.2%. It dates back to 1909 in the then-Bukedi District in Eastern Uganda, and has since spread to other parts of Eastern Uganda, including Busoga, Northern, and West Nile [7]. The purpose of its introduction was to support cotton and traditional cereals production.

Despite its benefits, the effective use of ATT in Uganda remains a persistent challenge. These include poor animal health and husbandry, inadequate access to veterinary services, limited farmer training, and the high initial cost of equipment [8]. Nevertheless, ATT aligns closely with the principles of sustainable agriculture and offers considerable potential to enhance productivity, conserve the environment, and strengthen the resilience of rural communities. Moreover, the absence of up-to-date, region-specific data hinders the development of targeted interventions to improve their effectiveness and sustainability. Previous studies across sub-Saharan Africa have shown that the success of ATT is influenced by various factors, including livestock availability, farmer education, market accessibility, and the presence of supportive policy frameworks [9].

In addressing these challenges, studies have been conducted. Key among these are by Blench [10] on history of animal traction in Africa, Zantsi & Bester [11] on benefits of animal traction to subsistence smallholder farmers, Daum et al. [2] on best fit approach of animal traction, two-wheel tractors or four-wheel tractors to guide farm mechanization in Africa, Okurut et al. [12] on constraints to utilization of draught animal power in Uganda, and Ayo-Odongo et al. [13] on improving on-farm transport using draught animal power.

However, limited research has examined the status of AT use in Uganda. The purpose of this study was to investigate prevailing practices, existing constraints, factors influencing adoption, and opportunities for animal traction technologies in the Busoga sub-region. The research question that guided this study was: What is the status of and opportunities for animal traction in the Busoga sub-region?

2. Materials and Methods

2.1. Study Area

Figures 1 and 2 show the eleven districts making-up Busoga sub-region and five districts where the study was conducted respectively. These figures were generated using Arc GIS 10.8. The study was conducted over two months from mid-March to early June 2024 in Buyende, Jinja, Kaliro, Kamuli, and Luuka districts (Figure 2).

Busoga sub-region, comprising eleven districts (Figure 1), is located in Eastern Uganda and is bordered by Lake Kyoga (north), the Victoria Nile (west), Lake Victoria (south), and the Mpologoma River (east). These water bodies shape their unique geography and cultural landscape, often referred to as an "island" by scholars [14] due to their natural boundaries.

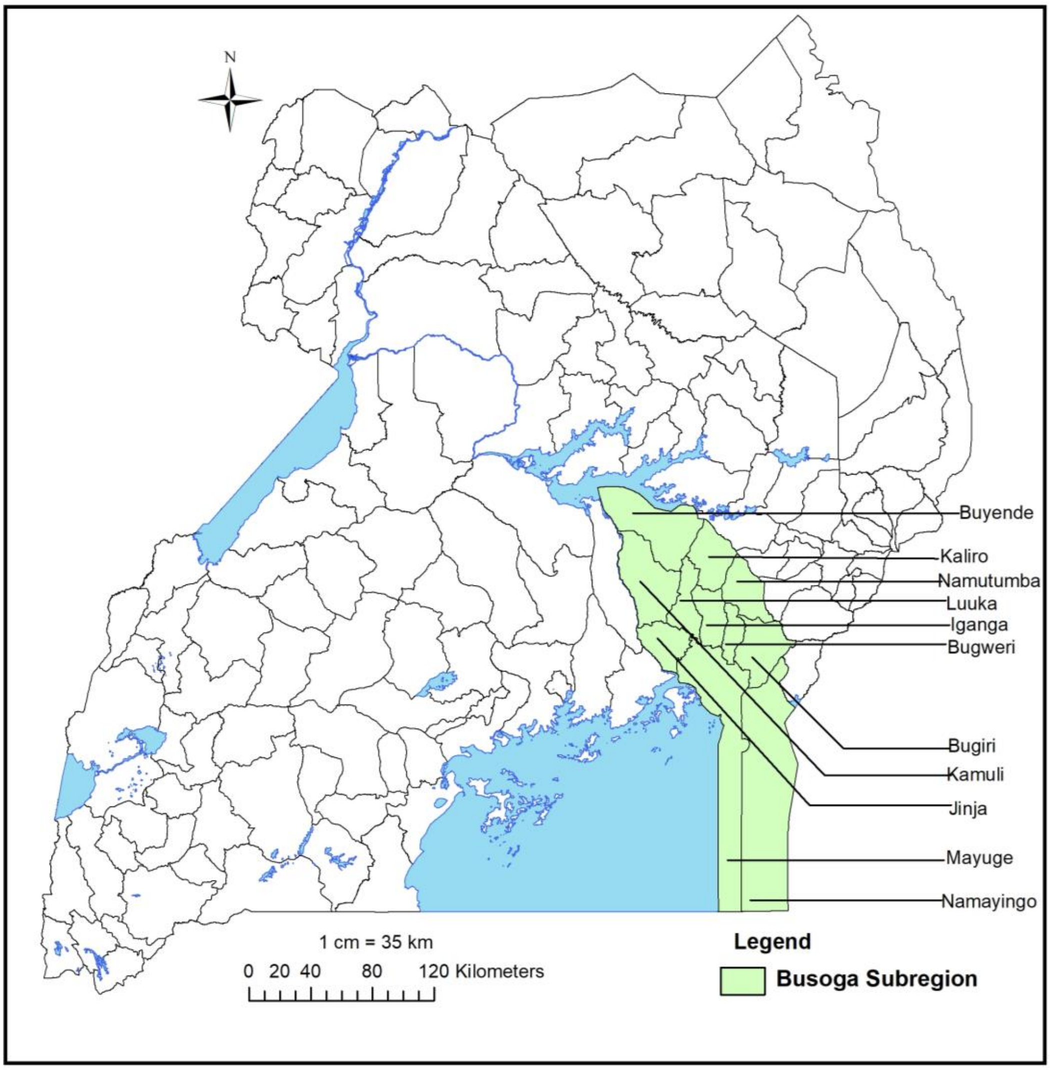


Figure 1. Map of Uganda showing the Busoga sub-region

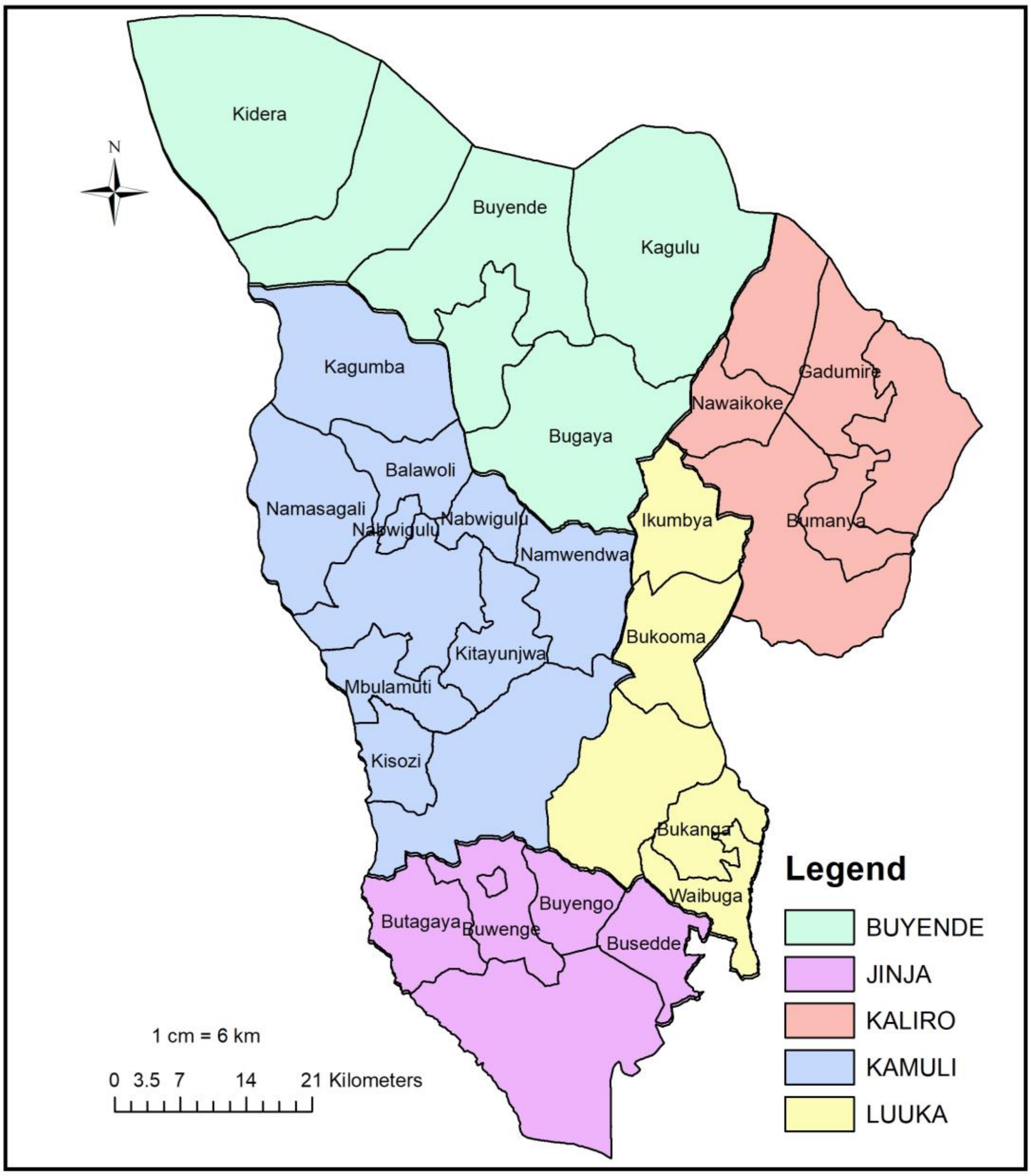


Figure 2. Map of Study districts and sub-counties

Busoga's strategic location has historically influenced trade, migration, and inter-ethnic relations. While the Basoga are the dominant ethnic group and Lusoga is the primary language, the region is ethnically diverse due to immigration and intermarriage. The sub-region's population exceeds 4.3 million [15], with most residents engaged in smallholder farming.

Agriculture is the mainstay, combining subsistence and commercial farming. Staple crops include maize, cassava, rice, banana, sweet potato, and beans, whereas key cash crops vary by district, including coffee, sugarcane, and cotton. Farmers also practice agroforestry, mixed cropping, and integrated livestock farming. Fishing is prominent in low-lying and riparian areas.

The region experiences a tropical savanna climate, with two rainy seasons (March-May, September-November) and annual rainfall ranging between 1,200-1,800 mm. Temperatures typically range from 20 ℃ to 30 ℃. Environmental issues such as flooding, wetland degradation, and periodic droughts are common and are influenced by population growth and climate change.

Socio-economically, Busoga is diverse, with uneven access to education, healthcare, and infrastructure. This heterogeneity affects farming systems and household decision-making. Urban centers such as Jinja and Kamuli act as commercial and service hubs, while rural areas remain agriculturally intensive. Most households are multi-generational, and youth contribute significantly to farming and labour. Rural-urban migration, especially among young adults, is evident.

2.2. Data Collection

Both primary and secondary data were collected using a combination of quantitative and qualitative methods. Quantitative data included proportions, costs, and applications, while qualitative data captured farmer experiences and perceptions.

Primary data collection involved face-to-face interviews, focus group discussions (FGDs), farm records reviews, and field observations. Tools used included structured questionnaires, interview guides, historical timelines, pairwise ranking, Likert scales, SWOT, and PESTEL analyses. Secondary data were sourced from government reports and agricultural literature.

FGDs utilized participatory, interactive techniques, while individual farm interviews were complemented by observation of animal-drawn equipment, live field operations, animal conditions, and local artisans. The study targeted smallholder farmers, both users and non-users of animal traction, and involved five respondent categories: farmers, technical staff, community leaders, equipment dealers, and makers of AT parts and spares.

The selection was guided by information in Figure 3 that was derived from the data extracted from the National Livestock Census of 2021 by UBOS [16]. The five districts were purposively selected, accounting for 55% of Busoga's cattle herd (Figure 3). Within each district, 60% of sub-counties were chosen based on topography, ADP prevalence, soil types, and dominant crop, totaling 23 sub-counties. Sample size for individual respondents was calculated using a modified Kish Leslie formula at 96% confidence level and 4% margin of error.

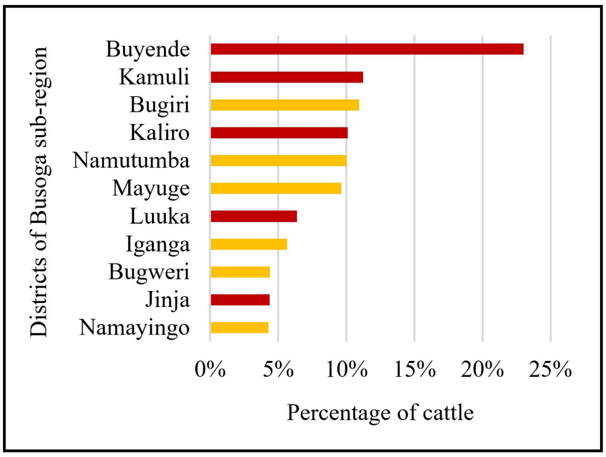


Figure 3. Proportion of Busoga Cattle Herd in each District

The 96% confidence level was guided by the need to balance statistical rigor with practical feasibility. This provided sufficient precision to ensure that the survey results were representative of the population. At the same time, it maximizes the use of limited resources for field data collection.

In total, 664 individual farmers were interviewed, and 230 participated in FGDs, yielding 962 farmer participants, 15.1% of whom were women. Additionally, 68 key informants were engaged. The district-wise breakdown of respondent categories is shown in Table 1.

Table 1. Number of respondents by category and district

District	Farmers	KIs	FGD	Total
Buyende	125	16	40	181
Jinja	90	12	40	142
Kaliro	93	7	30	130
Kamuli	246	20	80	346
Luuka	110	13	40	163
Total	664	68	230	962

2.3. Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) v17 and Microsoft Excel. Raw data were cleaned, coded, and analyzed using descriptive statistics (means, frequencies, percentages) to interpret both quantitative and qualitative inputs. SPSS enabled structured analysis and graphical outputs, while Excel supported initial processing and calculations, ensuring accurate and understandable results.

Given that the objective of the study was descriptive, to establish the current status and patterns of animal traction use, inferential analyses, including chi-square and regression, were not used. The focus was on generating reliable estimates of occurrences and distribution, which adequately supported descriptive statistics at the 96% confidence level.

3. Results

3.1. Current Status of ATT

3.1.1. Experience of Respondents on Animal Traction Use

Table 2 presents respondents' experiences with the use of AT. This indicates that 86.3% of respondents had used AT for more than five years. 13.7% of respondents had used AT for less than 5 years.

Table 2. Respondent Experience in Animal Traction

Experience in AT (Years)	Percent (%)
< 1	1.4
1-4	12.3
5-10	48.6
11-14	15.5
15-20	10.3
21-24	5.2
25-30	3.4
> 30	3.3
Total	100

3.1.2. Type of Draught Animals Used in Traction

Table 3 shows the common types of draught animals used in traction. Bulls (59.4%) and oxen (40.1%) constitute nearly all the draught animals used in the study area, with minimal use of donkeys (0.2%) and cows (0.3%). The cattle breeds in use were predominantly indigenous, comprising short-horn Zebu (Figure 4) and long-horn Ankole (Figure 5) breeds.

Table 3. Common Draught Animals Among Respondents

Type of Draught Animal	Percent (%)
Oxen (Castrated bulls)	40.1
Bulls	59.4
Cows	0.3
Donkeys	0.2
Total	100

Figure 4. Short Horn Zebu

Figure 5. Long Horn Ankole

3.1.3. Mode of Using Draught Animals

Draught animals are mainly used in pairs. Table 4 shows the draught animal teams used in traction. The majority of respondents (80.2%) used one pair, 14% respondents used 2 pairs, and a few (0.8%) used 3 pairs of draught animals.

Table 4. Draught animal Teams

Draught animals	Percent (%)
1 Pair	80.2
2 Pairs	14.0
3 Pairs	0.8
1 Animal	5.0
Total	100

3.1.4. Distribution of Animal Traction Equipment

The survey revealed that mouldboard ploughs, ox-carts and cane jaggery mills were the main animal traction (AT) technologies owned in the Busoga sub-region at 91.9% 17.8%, and 5.1% respectively. Geographical analysis of plough ownership indicated that Kamuli district had the highest concentration (34.9%), followed by Buyende (17.6%), Luuka (15.5%), Kaliro (13.6%) and Jinja had the lowest proportion (10.2%).

3.1.5. Distribution of Draught Animals

Table 5 shows the distribution of draught animals owned by households. This indicated that 66.3% of respondents owned draught animals, of whom only 5.4% were women. Among non-owners, 26.3% were women. These farmers access draught animal services by hiring, borrowing from a relative, or sharing someone else's draught animals while using their own plough, resulting in delayed ploughing, less land properly cultivated, higher production costs, and lower production.

Table 5. Number of Draught Animals Owned by Households

Number of Draught Animals	Number of Respondents	Male	Female	Percent Respondents (%)
One	45	43	2	6.8
Two	307	289	18	46.2
Three	19	18	1	2.9
Four	55	52	3	8.3
More than 4	14	14	0	2.1
Zero	224	165	59	33.7
Total	664	581	83	100

3.1.6. Costs Related to Animal Traction Technology

The average cost of an AT package was UGX 4,795,000, equivalent to USD 1,370 at an exchange rate of 1 USD to UGX 3,500. This included a pair of bulls, a plough, a cart, a plough yoke, a transport yoke, and 2 sets of halters. Table 6 shows details of the cost for the AT package.

Table 6. Average Cost of the different AT Technologies

Item	Type of AT Technology	Average Cost in UGX
1	One pair of bulls aged 1.5 to 2 years	2,500,000
2	Ox-plough	325,000
3	Ox-cart	1,900,000
4	Cane Jaggery mill	1,000,000
5	Plough yoke plus skies	30,000
6	Transport yoke plus skies	30,000
7	Jaggery milling yoke plus skies	50,000
8	Halters (2 sets)	10,000

3.1.7. Application in Farming Practices

Animal traction was mainly used for ploughing (78% of respondents), followed by transportation (10%), and cane jaggery milling (2%). Figures 6, 7, and 8 show ploughing, transportation, and cane jaggery milling. There was no reported use of draught animals for other farming operations such as harrowing, ridging, planting, weeding, or spraying. The limited adoption of these tasks was attributed to a lack of knowledge, the absence of appropriate AT equipment, and financial constraints.

Figure 6. Ploughing

Figure 7. Transporting

Figure 8. Cane Jaggery Milling

Field observations and focus group discussions revealed that animals worked for 4 hours per day, ploughing between 0.5 and 1 acre, depending on field conditions, including soil type, vegetation cover, terrain, and operator-animal experience.

In addition, FGD revealed the use of AT in conservation agriculture practices such as contour ploughing to minimize soil erosion, shallow tillage to conserve soil health, and integrated crop-livestock systems, where animal manure was deliberately accumulated and incorporated into soil to enhance fertility.

3.1.8. Application in Crop Cultivation

Figure 9 shows crops grown using AT. AT was used to cultivate more than 14 crops. These include maize, cassava, beans, sweet potato, rice, groundnuts, soybeans, peas, green gram, sugarcane, sorghum, millet, coffee, tomato, banana, cabbage, and cotton. Among these, the four main crops cultivated were maize, cassava, beans, and sweet potato. Maize was the main widely grown crop (26%), followed by cassava (17.2%), beans (10.9%), and sweet potato (10%).

3.1.9. Sources of AT Knowledge and Skills Acquisition

Of the 664 farmers interviewed, 91% acquired the knowledge and skills through on-the-job training provided by their parents or neighbours. While 9% through local animal trainers. The results further indicated that 37 local AT trainers were present in the study area.

These indicate that the AT farmers' know-how depends solely on local expertise. It is worth noting that these local AT trainers have skills only in ploughing, transport, and cane jaggery milling operations, making respective yokes, basic repairs, and care for oxen and bulls. Therefore, they transfer limited knowledge and skills on AT use to farmers. This, therefore, justifies the limitation of AT application to ploughing, transportation, and cane jaggery milling.

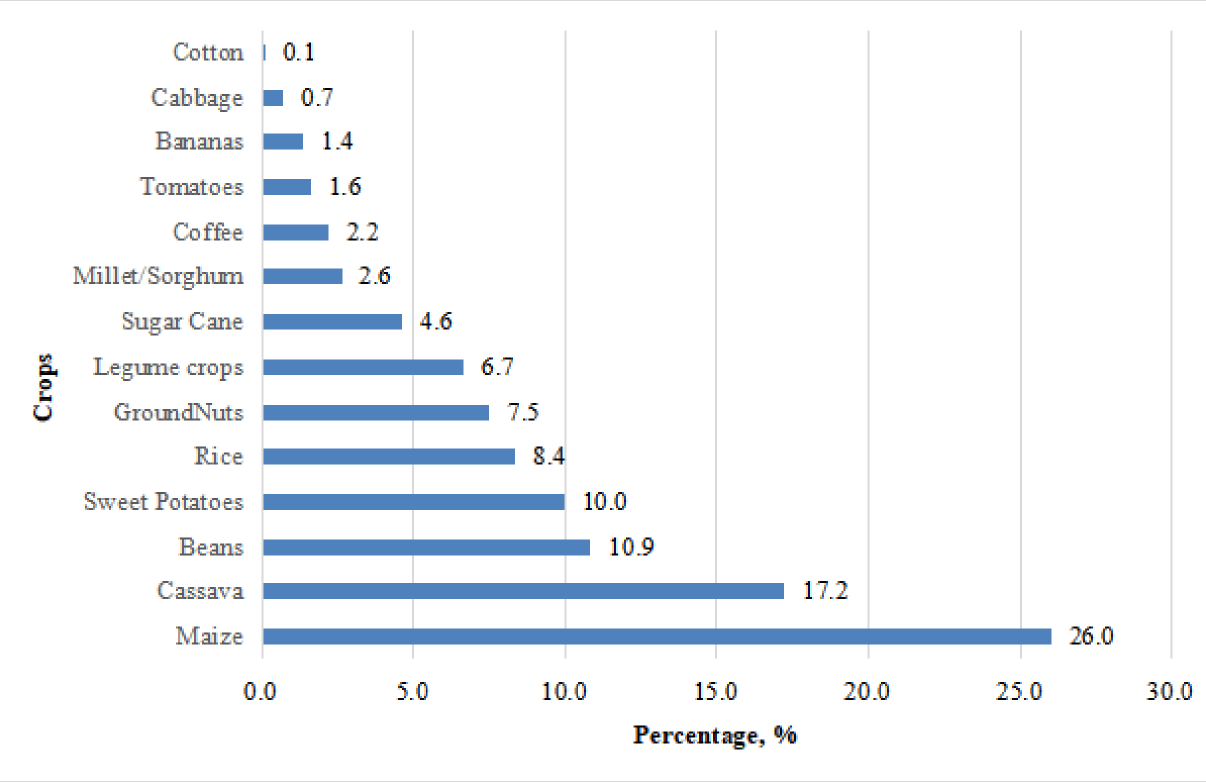


Figure 9. Crops grown using AT

3.1.10. Care and Management of Draught Animals

Farmers' understanding of draught animal care was largely limited to the provision of feed, water, treatment, and vaccination. Management aspects such as housing quality, prevention of overworking, and avoidance of mistreatment (by beating) were not reported by respondents, indicating a narrow conceptualization of animal welfare.

Feeding practices reported by farmers included free-range grazing, tethering, and zero-grazing systems. Across all the surveyed districts, the dominant feeding method was a combination of free-range grazing and tethering, reported by an average of 63% respondents. This feeding practice differed significantly across districts (χ^2 test, $p=0.026$), indicating spatial variation in grazing access and management. Farmers attributed their reliance on this mixed system to the continued availability of some grazing land. However, respondents reported that grazing land was declining due to population growth and increasing sugar cane cultivation.

60.2% farmers practiced supplementary feeding. Common supplements included maize bran, prominent grain, elephant grass, potato vines, and sugarcane residues, but lacked protein-rich and mineral feeds. There were no legumes and mineral licks among the supplementary feeds. The absence of legumes and mineral licks was qualitatively attributed to limited farmer knowledge on balanced rations, low on-farm availability of forage legumes, and high cost of commercial mineral licks.

Water for draught animals was sourced from boreholes (58%) and rivers (16%), with the remaining proportion likely accessing water opportunistically while grazing. Farmers acknowledged that draught animals often drank water at grazing sites without direct supervision. Such unscheduled access may result in irregular watering regimes, which are suboptimal for maintaining animal health and work performance, particularly during peak traction periods.

Housing of draught animals was predominantly outdoors, with more than 99.4% respondents reporting the absence of permanent housing structures. High construction costs were cited as the primary constraint on improving housing. Animals were typically kept in open household kraals, communal kraals, under simple constructed shades, or tethered outdoors within the homestead, reflecting minimal investment in housing infrastructure.

3.1.11. AT Equipment Repair Providers

Figure 10 shows AT equipment repair providers. It was reported that repairs were mainly conducted by farmers themselves (myself), fabricators, and local blacksmiths. 29.6% of respondent farmers were able to undertake basic repair of their AT implements themselves. This, therefore, meant that the majority (70.4%) of the respondents cannot repair their AT equipment. This is a local business opportunity worth strengthening.

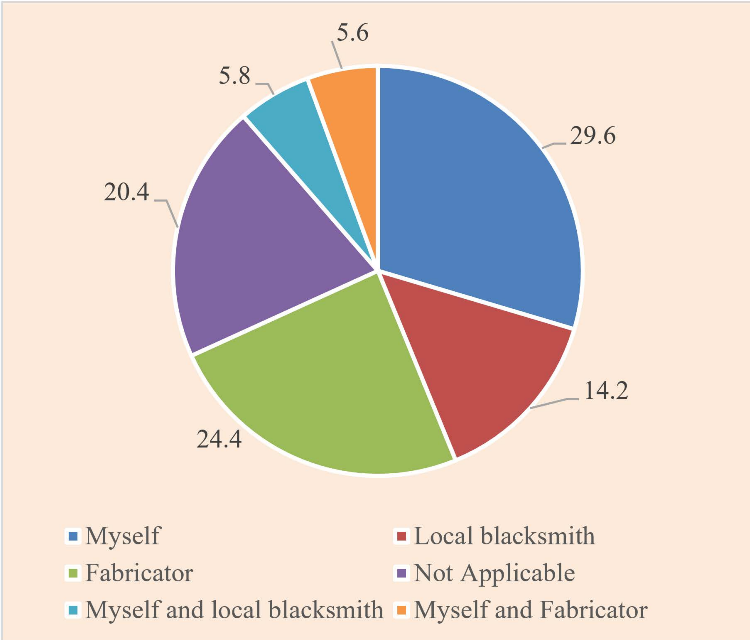


Figure 10. AT Equipment Repair Providers

This would require training farmers and the provision of repair toolkits (spanners 17, 19, and 22; chisel; hammer; and assorted plough bolts). Of the farmers interviewed, 20.4% did not respond, which may indicate that they hire AT services and therefore that repair issues were not their responsibility.

3.1.12. Community Capacity to Support AT

The study revealed that 33.7% of farmers hired AT services as they did not own any draught animals. This demonstrates the critical role of AT hire service providers. AT hire service provision is either by a farmer owning draught animals or a private person contracted to operate the business. In this contracting arrangement, proceeds are shared at 60% to the owner and 40% to the contractor. In addition, the contractor grazes the draught animals. The owner treats the animals.

The study area had at least 425 AT hire service providers, 126 equipment dealers, 112 blacksmiths engaged in AT implement repairs and making spare parts, 97 veterinary officers, 127 community-based veterinary helpers, 37 local AT trainers, and 258 yoke makers, though many of their products (yokes) were not to standard and poorly finished. The number and capacity of each service provider category varied across the study area.

AT hire services providers operate informally and do not maintain transaction records. A farmer in need of the service contacts the AT service provider to inspect the work and agree on the cost and the date on which the work will be performed. Farmers reported that AT service providers often fail to meet the scheduled date, resulting in delays in the cropping season. Despite some delays, farmers were satisfied with the quality of the services provided. There is therefore a need to strengthen these services by training hire service providers in business operations, management, and record-keeping.

3.2. Barriers to Adoption and Challenges

3.2.1. Barriers to Effective Use of Animal Traction Technology

The study identified a range of interrelated barriers to the adoption and effective use of animal traction (AT) technology among farmers. These were categorized into six thematic areas: knowledge and skills, animal health and welfare, economic and financial challenges, equipment and infrastructure limitations, environmental constraints, and social and institutional factors. A summary of the barriers under each of these thematic areas is presented in Figure 11.

Knowledge and Skills: The barriers under this thematic area included limited technical knowledge, inadequate training in AT techniques and equipment maintenance, and insufficient extension services reducing adoption and efficiency.

Animal Health and Welfare: In this thematic area the barriers included high incidence of diseases and parasites such as tick and tsetse flies, costly and scarce veterinary services, and poor animal care practices compromising animal productivity and reliability.

Economic and Financial: High costs of draught animals and AT equipment, coupled with limited access to credit, restrict farmers' ability to invest in and sustain AT use, were the barriers identified in this thematic area.

Equipment and Infrastructure: In this thematic area, the barriers included limited availability of AT equipment, spare parts, and affordable repair services, particularly in remote areas, resulting in operational inefficiencies.

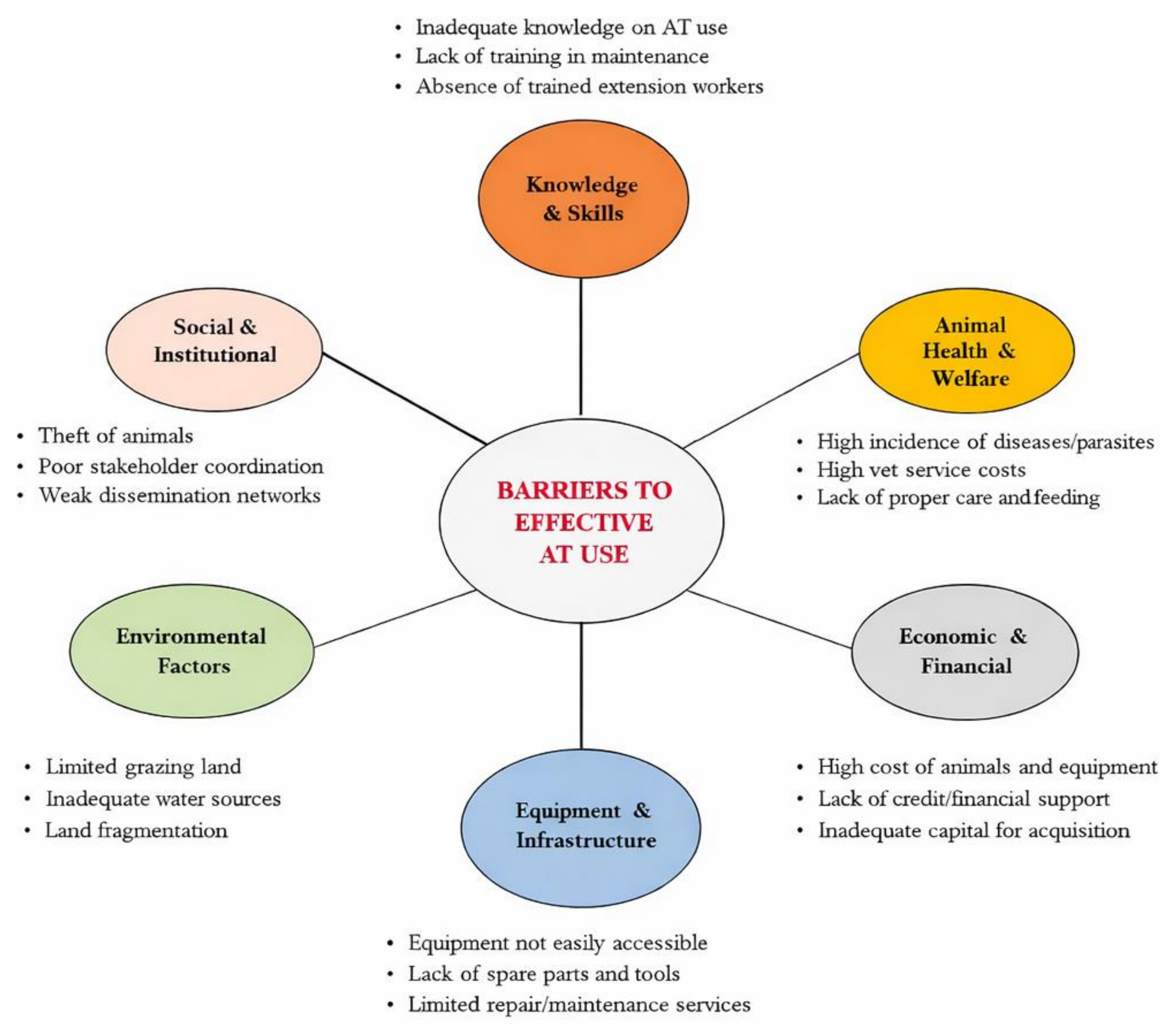


Figure 11. Thematic areas of interrelated barriers to effective AT use

Environmental Factors: These included inadequate grazing land, scarce water sources, and fragmented plots, which limited the maintenance and use of draft animals.

Social and Institutional: Issues included livestock theft, weak institutional support, poor coordination among stakeholders, and a lack of trained extension personnel, all of which impede the dissemination and adoption of technology.

3.2.2. Factors Influencing Adoption and Sustainable Use of Animal Traction

The study identified a range of interrelated social, cultural, political, economic, technological, environmental, and legal factors influencing the adoption and sustainable use of AT technology. The findings are presented thematically as follows:

Social Factors: Positive community perceptions and willingness to hire or provide AT services support adoption. Most farmers perceived AT as a beneficial innovation that enhances agricultural productivity and reduces household labour burdens, thereby improving income and reducing domestic conflict. However, gender disparities, rooted in traditional roles, excluded women from decision-making and usage, limiting equitable access.

Cultural Factors: Shared labour norms and community support promoted AT use, but male-controlled traditions and resistance to change among older farmers inhibited broader adoption.

Political Factors: Government policies, including Vision 2040, NDP IV, and institutional support (NARO), encouraged AT uptake. Local leaders often promoted AT through campaigns. However, a bias towards motorized mechanization risks marginalizing AT in long-term planning.

Economic Factors: Land availability, veterinary services, and perceived productivity benefits encouraged adoption. Yet, high poverty levels, equipment costs, and livestock theft remained major bottlenecks.

Technological Factors: AT was reported as user-friendly, cost-effective, and adaptable to varied terrains. Access to quality draught animals and basic spare parts supported adoption. Nonetheless, poor-quality implements and harnesses, as well as a lack of training in sustainable land-use practices for AT, undermined effectiveness.

Environmental Factors: Favourable flat terrain and the use of animal waste as an organic fertilizer or for biogas production enhanced AT's application. However, climate change effects, such as droughts, erratic rainfall patterns, and floods, led to pasture loss, threatening effective AT utilization and sustainability.

Legal and Institutional Factors: Policies and institutional frameworks facilitated AT integration into mechanization strategies. Although wetland cultivation was restricted, access for draught animals to graze and obtain water remained permitted, thereby sustaining the continued use of AT.

3.3. Opportunities for Development and Expansion

The SWOT analysis of animal traction (AT) in Busoga identified several strategic opportunities for sustainable intensification and up-scaling, tailored to local strengths and conditions. The key summarized results included:

3.3.1. Promotion of Climate-Smart AT Practices

AT-compatible techniques such as ripping, tillage ridging, and minimum tillage can enhance soil health and water retention. These are well-suited to Busoga's flat, light soils, with strong potential for piloting and scaling the technology.

3.3.2. Strengthening of Draught Animal Breeding and Management Systems

Leveraging existing breeding programs at the National Semi-Arid Resources Research Institute (NaSARRI) of NARO, and establishing decentralized hubs, can supply improved draught breeds and deliver training in animal husbandry, disease control, and ATT.

3.3.3. Development of Local AT Value Chains

Organizing the network of local artisans, yoke makers, and blacksmiths into groups can enhance training, financing, and business support, thereby building a reliable supply of high-quality AT equipment and services, thereby boosting access and efficiency.

3.3.4. Market Driven AT Adoption

Rising food demand in Busoga and neighbouring markets provides incentives for smallholders to adopt AT to increase productivity and profitability, supported by improved market linkages and cooperatives.

3.3.5. AT Integration in Sugarcane Zones

Despite challenges posed by grazing land, sugarcane areas offer opportunities for integration. Intercropping cane with fodder crops or legumes and using AT for tillage and transport can sustain livestock and improve system productivity.

3.3.6. Tailored Training and Multi-Stakeholder Capacity Building across the AT Value Chain

The study identified critical training gaps among multiple stakeholders across the animal traction (AT) value chain in the Busoga subregion. These deficiencies limit the effective adoption, use, and sustainability of AT technologies. Key findings by stakeholder group included:

Farmers: Most farmers (91%) relied on informal sources of AT knowledge, primarily from family or neighbours, and received limited formal training due to the inadequate technical expertise of local trainers. Training was focused narrowly on ploughing, neglecting operations such as harrowing, planting, weeding, harvesting, and equipment maintenance. Over 70% lacked skills in basic repairs and maintenance of AT equipment and harnesses. To improve AT performance, training priorities should include comprehensive AT applications, animal care and management, basic equipment repair and maintenance, and humane animal harnessing practices. In addition, these communities should be equipped with toolkits for on-farm repairs and maintenance.

AT Hire Service Providers: Approximately 34% of farmers relied on informal AT hire services that lacked professionalism and a formal business structure. To enhance service provision, skills in business and AT operations management (record-keeping, scheduling), service diversification (harrowing, planting, weeding, ridging, harvesting), and customer relations should be strengthened to improve reliability and profitability.

Local Blacksmiths: While 112 blacksmiths were identified, many lacked the capacity to produce quality AT parts. To enhance this group's performance, training should be provided in the fabrication of AT components, the use and maintenance of metalworking tools, and enterprise management to ensure the availability of affordable, timely spare parts.

AT Equipment Dealers: The 126 equipment dealers primarily stocked basic plough spares and showed minimal engagement in farmers' education or support. Training is needed in stock diversification, customer advisory services, and basic business development to meet the broader demand for AT equipment.

Veterinary Service Providers: With only 97 veterinary officers, compared with 127 semi-skilled community helpers, animal healthcare was inconsistent. Training is required in diagnosing and treating work-related conditions, in drug safety, and in preventive care to support animal welfare during AT use.

Local AT Trainers: Only 37 trainers were identified, most with limited expertise beyond ploughing and yoke making. Upskilling in broader AT operations (harrowing, ridging, planting, weeding) and in adult learning methods is crucial to enhancing their impact as community educators.

Yoke Makers: Among 258 yoke makers, poor craftsmanship led to animal injuries. Training should focus on ergonomic design, appropriate yoke material selection, techniques for comfort and durability, and the standardization of yoke dimensions to improve animal comfort and work efficiency.

3.3.7. Policy Engagement

AT remains underrepresented in national mechanization strategies. Advocacy is needed to integrate AT as a complementary option to motorization for smallholder farmers, thereby enhancing mechanization in sub-Saharan African countries.

3.3.8. Digital Innovation

Leveraging mobile technology can improve access to information on animal health, weather, market prices, and AT services. This can support better decision-making among farmers and service providers.

3.3.9. Equipment Banks and Service Hubs

Community-based equipment banks and rental hubs can increase access to AT implements for smallholders, reducing capital burdens and enhancing productivity.

4. Discussion

4.1. Current Utilization of ATT

Findings indicate that mouldboard ploughs overwhelmingly dominate ATT use in Busoga, with over 90% of respondents reporting ownership of one. This level of reliance is substantially higher than national estimates, which indicate that approximately 25-35% of Ugandan smallholder households use animal traction in some form, with a higher concentration in Eastern and Northern regions compared to Central and Western Uganda. The exceptionally high reliance on ploughs in Busoga underscores the continued importance of animal-powered tillage for ensuring timely land preparation under rainfed farming systems, where delayed planting can result in yield losses [17].

In contrast, the relatively low ownership of ox-carts (17.8%) and the near obsolescence of cane jaggery mills (5.1%) indicate a functional narrowing of ATT use to ploughing. Nationally, the ox-cart ownership rate ranges from 20% to 30% [20], suggesting that Busoga underutilizes ATT for transport operations. This narrow application spectrum highlights significant untapped potential to diversify ATT beyond ploughing to other farm operations, including harrowing, planting, weeding, spraying, and harvesting.

Spatial disparities in plough ownership, particularly the concentration in Kamuli district (35%), may suggest uneven access to extension services, infrastructure, and institutional support. Similar intra-regional disparities have been reported elsewhere in Uganda and Eastern Africa, often reflecting differences in local government prioritization and project exposure rather than agroecological suitability alone. These findings point to the need for geographically differentiated mechanization policies that respond to district-level needs.

Among the AT implements, mouldboard ploughs were prioritized due to their versatility and critical role in soil preparation, a labour-intensive, time-sensitive operation essential for timely planting. In contrast, ox-carts were valued for their multi-functionality, providing labour-saving benefits and serving both on-farm and off-farm transport needs throughout the year. Cane jaggery mills were the least used and are considered obsolete, given the presence of modern sugarcane processing facilities in the subregion.

4.2. Traction Animal Usage

The predominance of indigenous bulls (59.4%) and oxen (40.1%) as sources of draught power aligns with national and regional livestock utilization patterns, where male cattle are preferred for traction due to superior strength and lower reproductive opportunity costs [2]. This pattern corresponds to the region’s dependence on indigenous cattle breeds such as the Zebu and Ankole, which are well adapted to local environmental conditions and exhibit resilience to disease, feed scarcity, and climate stress [18].

The widespread use of a single pair of draught animals (80.2%) mirrors national landholding patterns, in which most smallholders cultivate less than 3 hectares, thereby maximizing economies of scale and making animal traction more cost-effective than tractor-based mechanization [2]. However, the localized use of 3 pairs of draught animals in sugarcane-growing areas demonstrates the technical flexibility of ATT in responding to higher draft requirements, particularly in fields with dense fibrous root systems. This finding challenges the perception of animal traction as a rigid or inferior technology and supports arguments for its continued relevance within context-specific mechanization pathways.

The limited use of single draught animals (5%), primarily for cane jaggery milling or through farmer partnerships, reflects both innovation and constraint. While such practices demonstrate adaptive coping strategies under scarcity, they also point to capital and knowledge barriers that constrain efficient animal utilization. Policy interventions that improve access to draught animals and promote training on optimal pairing could substantially enhance productivity.

4.3. Underutilization of AT in Broader Farm Operations

Despite widespread use of ATT for ploughing (78%), its application in other farm operations, such as harrowing, planting, weeding, harvesting, and spraying, remains minimal. This pattern is consistent with evidence from East Africa, where animal traction is similarly concentrated in primary tillage due to limited implement availability, weak supply chains, and inadequate extension support [19]. Consequently, the full agronomic and economic potential of ATT remains largely unrealized.

From a policy perspective, this underutilization represents a missed opportunity to address rural labour shortages, reduce drudgery, and improve timeliness across the cropping calendar. Increased investment in adaptive research, local fabrication of complementary implements, and extension messaging that promotes multifunctional ATT systems could significantly enhance productivity and farm resilience.

The observed unintentional adoption of conservation-oriented practices, such as shallow tillage and contour ploughing, provides an important entry point for integrating ATT into national climate-smart agriculture and sustainable land management strategies [18]. Supporting these practices through targeted training and policy recognition could generate both productivity and environmental benefits.

4.4. Barriers to ATT Expansion

The six interrelated constraint categories, including knowledge, animal health, finance, infrastructure, environment, and institutional support, underscore that ATT adoption and effective use are shaped by systemic factors rather than technology alone. The finding that 91% of farmers rely on informal learning pathways reflects a widespread capacity gap in equipment maintenance, animal health management, and efficient operation, consistent with national assessments of mechanization service delivery in Uganda.

High entry costs for implements and animals, coupled with limited access to credit, disproportionately constrain poorer households and women. These challenges echo broader mechanization constraints in sub-Saharan Africa, where fragmented supply chains, weak financial services, and limited public investment continue to hinder the uptake of inclusive technologies [20]. Environmental pressures, including declining grazing land, erratic rainfall, and increased disease incidence, further hinder the adoption of AT.

Gendered exclusion from ATT activities reflects entrenched socio-cultural norms that limit women’s access to productive assets and training, reinforcing inequalities in labour allocation and decision-making [21]. Addressing these barriers requires integrated, gender-responsive interventions rather than isolated technical solutions.

4.5. Enabling Environment and Strategic Opportunities

Despite these constraints, Busoga exhibits a relatively strong enabling environment for ATT revitalization. Positive farmer perceptions, alignment with Uganda’s Vision 2040, and sustained demand for tillage and transport services position ATT as a viable pathway to inclusive and climate-resilient mechanization. Compared to tractor-based systems, animal traction remains more accessible and adaptable for the majority of smallholders operating under capital and infrastructure constraints [2].

Opportunities exist to integrate ATT more deliberately into sustainable land management initiatives, including minimum tillage and organic nutrient recycling. Decentralized breeding, training, and demonstration centers, primarily through partnerships with institutions such as NARO, could improve the quality of draught animals and operator skills. Strengthening localized ATT value chains by organizing blacksmithing, yoke-making, and equipment distribution could simultaneously enhance service reliability and rural employment, consistent with a report by the FAO and the African Union.

4.6. Transformational Role of Training and Digital Innovation

The study highlights a critical need for structured training across all ATT stakeholders, extending beyond technical skills to include business development, pricing, and service management. These competencies are essential for transitioning ATT from subsistence use to a professionalized mechanization service model.

Digital innovations offer scalable solutions to persistent information and coordination gaps. Mobile-based platforms for animal health advice, weather forecasting, market information, and service directories have demonstrated potential to improve decision-making and system efficiency in the smallholder context [20]. Integrating such tools into extension systems could significantly enhance the attractiveness and performance of ATT, particularly among youth.

4.7. Policy Advocacy and Institutional Integration

The marginalization of ATT in national mechanization strategies represents a critical policy blind spot, given that a substantial proportion of Ugandan farmers continue to rely on animal traction. The findings from Busoga reinforce the argument that ATT should be repositioned as a complementary and context-appropriate technology rather than a transitional or obsolete one.

Policy advocacy is therefore required to ensure the explicit integration of ATT into national and district-level agricultural development frameworks. This includes dedicated funding for research and extension, inclusion of ATT in mechanization credit and subsidy schemes, and stronger coordination among local governments, NARO, and development partners. Such institutional integration would enhance inclusivity, resilience, and sustainability in Uganda’s smallholder farming systems.

5. Conclusions

The results highlight that while animal traction remains a cornerstone of smallholder agriculture in Busoga, its application is suboptimal and constrained by systemic issues. However, the enabling environment, strong interest among farmers, and strategic fit with conservation agriculture provide a solid foundation for expansion. By addressing key constraints, animal traction technology (ATT) can play a transformative role in enhancing the productivity, sustainability, and resilience of smallholder agriculture in Busoga and similar agroecological regions. Future empirical work should focus on assessing the economic viability of AT training centers.

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Data Availability Statement

Data is readily available upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to this work.

Author Contribution

1. Samuel Okurut - Conceptualization, Methodology, Data Collection, Investigation, Resources, Writing—Original Draft Preparation, Visualization, Project Administration
2. Ronald Walozi - Data Collection, Writing—Review & Editing
3. Alphonse Candia - Data Collection, Writing—Review & Editing
4. Richard Saasa - Data Collection, Writing—Review & Editing
5. Arnold Oule - Data Collection, Writing—Review & Editing
6. Ronald Balibuzani - Data Collection, Writing—Review & Editing
7. Ibrahim Mbadhi - Data Collection, Writing—Review & Editing

Clinical Trial Declaration

This article has not generated data through a clinical trial. Necessary registrations are not applicable.

Ethics Declaration

I confirm that this study respected the rights, traditions, and livelihoods of the local communities. I further confirm that all the data collected was reported honestly without falsification, fabrication, or misinterpretation. No ethical approvals were required since there were no direct tests on humans or animals.

Consent to Participant Declaration

A consent was sought from participants involved in the research, as respondents.

Consent to Publish Declaration

No person’s unpublished data is in this manuscript. It is therefore not applicable.

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