The sub Saharan Journal of Social Sciences and Humanities
(SJSSH)
ISSN: 2619-8894 (Online), 2619- 8851 (Print)

Association Between Socioeconomic Status and Antimicrobial Use Patterns Among Broiler Farmers in Kilimanjaro and Mwanza Regions, Tanzania

[1]Norbert Bilaba, Esron Karimuribo[2], Edwin E. Ngowi [3] and Suzana S. Nyanda[4]

[1]Department of Veterinary Medicine and Public Health, Sokoine University of Agriculture, Morogoro, Tanzania. Email: norbertmgalaganza@gmail.com

[2] Department of Veterinary Medicine and Public Health, Sokoine University of Agriculture, Morogoro, Tanzania. Email: karimuribo@sua.ac.tz

[3]Department of Development & Strategic Studies, Sokoine University of Agriculture, Morogoro, Tanzania. Email: edwin.ngowi@sua.ac.tz

[4]Department of Policy, Planning & Management, Sokoine University of Agriculture, Morogoro, Tanzania. Email: suzy_nyanda@sua.ac.tz

Received: October 21, 2025; **Accepted:** February 21, 2026; **Published:** March 12, 2026

Abstract: *Antimicrobial resistance (AMR) poses a critical global health threat, with agricultural antimicrobial use (AMU); particularly in poultry systems; representing a major contributor, yet evidence on how socioeconomic and contextual factors jointly shape AMU patterns in low-resource settings remains limited. This study investigated the association between socioeconomic characteristics and AMU practices among broiler farmers in Tanzania's Kilimanjaro and Mwanza regions, examining both prevalence and frequency of antimicrobial application. Using a mixed-methods cross-sectional design, we surveyed 246 broiler farmers and conducted qualitative interviews to contextualize quantitative findings. Results revealed significant regional disparities: Mwanza exhibited substantially higher AMU prevalence (91.1% vs. 81.3%; $\chi^2=10.5$, $p<0.001$) and more frequent usage patterns (daily use: 35.0% vs. 29.3%) compared to Kilimanjaro. Training emerged as the strongest protective factor, reducing AMU odds by 95.6% (OR=0.044, 95% CI: 0.004–0.458; p=0.011) and decreasing usage frequency (OR=0.149, 95% CI: 0.028–0.780; p=0.024), though qualitative findings revealed limited training accessibility. Larger family size similarly reduced frequent AMU (OR=0.599, 95% CI: 0.424–0.847; p=0.0037). Critically, significant interaction effects revealed that education combined with training unexpectedly increased both AMU likelihood (OR=4.01; p=0.048) and frequency (OR=2.20; p=0.046), suggesting a "competency paradox" where knowledge may foster overconfidence in autonomous antimicrobial administration. Similarly, farming experience interacting with larger flock size increased usage frequency (OR=1.20; p=0.035), indicating that production intensification pressures may override experiential caution. These findings demonstrate that AMU practices emerge from complex intersections of socioeconomic position, knowledge acquisition, and structural constraints rather than from individual factors in isolation. Effective AMU stewardship in Tanzanian broiler systems therefore requires contextually-adapted, socioeconomic-responsive interventions that address not only farmer education but also the institutional, regulatory, and economic environments shaping antimicrobial dependence, including gender-sensitive extension services, strengthened veterinary oversight, and production system modifications that reduce disease pressure.*

Keywords: *Antimicrobial resistance, Broiler farming, Antimicrobial usage patterns, Socio-economic factors, public health, Tanzania*

1. Background Information

Antimicrobial resistance (AMR) has emerged as one of the most pressing public health crises of the twenty-first century, threatening to reverse decades of medical progress and undermine the effectiveness of modern medicine globally (Mukhopadhyay, Peng, & Tun, 2025). The World Health Organization (WHO) has identified AMR among the top ten global health threats, with recent estimates indicating that approximately 1.3 million deaths annually are directly attributable to resistant bacterial infections (Mukhopadhyay *et al.,* 2025). The 2025 WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) report reveals a stark reality: 17.2% of laboratory-confirmed bacterial infections globally, approximately one in six, now involve antibiotic-resistant pathogens, with resistance increasing in 40% of monitored pathogen-antibiotic combinations between 2018 and 2023 (World Health Organization, 2025; Halsey, 2025). This accelerating trajectory is particularly pronounced among Gram-negative bacteria such as Escherichia coli and Klebsiella pneumoniae, where resistance to critically important antimicrobials, including third-generation cephalosporins and carbapenems, now exceeds 70% in some African settings (Pramanik, 2025). The implications extend beyond human health, threatening food security, livestock productivity, and the economic livelihoods of millions who depend on animal agriculture (Lhermie *et al.,* 2019).

The agricultural sector plays a pivotal role in the AMR crisis, accounting for more than 70% of global antimicrobial consumption (Lhermie *et al.,* 2019). Antimicrobial use (AMU) in food-producing animals serves multiple purposes: therapeutic treatment of clinical disease, metaphylaxis during outbreaks, and in many low- and middle-income country (LMIC) contexts compensation for inadequate biosecurity, limited veterinary access, and suboptimal housing conditions (Jacobsen *et al.,* 2025). Poultry production, in particular, has emerged as a critical node in the AMR-AMU nexus due to its rapid growth, intensification, and integration into both subsistence and commercial farming systems across sub-Saharan Africa (Jacobsen *et al.,* 2025). As the demand for animal-source proteins rises with population growth and urbanisation, antimicrobial consumption in livestock is projected to increase by 53% globally by 2030, with the fastest growth occurring in African LMICs (Lhermie *et al.,* 2019).

Sub-Saharan Africa bears a disproportionate burden of AMR, with the region recording the highest rates of AMR-attributable deaths globally, 50% higher than the global average (Mukhopadhyay *et al.,* 2025). This vulnerability stems from a confluence of structural factors: weak regulatory frameworks governing antimicrobial access and use, limited veterinary and diagnostic services, high prevalence of infectious diseases, and the pervasive sale of over-the-counter antibiotics through informal agro-veterinary outlets (Jacobsen *et al.,* 2025). Recent qualitative research from Nigeria; sub-Saharan Africa's second-largest poultry producer; identified three interrelated barriers to prudent AMU among poultry farmers: issues of access (time, money, laboratory services, and expertise), lack of knowledge stemming from inadequate training and poor farmer-veterinarian relationships, and diffusion of responsibility among government, animal health professionals, and farmers themselves (Jacobsen *et al.,* 2025). These findings resonate across the region, suggesting that AMU practices are shaped not merely by individual farmer characteristics but by the broader social, economic, and institutional environments in which farming occurs.

The recognition that AMU behaviours are embedded within complex social-ecological systems has prompted growing scholarly attention to the socioeconomic determinants of antimicrobial practices in livestock production. Research across LMIC contexts has demonstrated that factors such as educational attainment, income sources, farming experience, household composition, and access to training significantly influence farmers' decisions regarding antimicrobial use (Lhermie *et al.,* 2019; Jacobsen *et al.,* 2025). For instance, studies have shown that formal education may paradoxically increase AMU by enhancing farmers' confidence in autonomous medication administration, while training in animal health management tends to promote more judicious use (Jacobsen *et al.,* 2025). Gender dynamics further complicate this picture: women, who typically assume primary responsibility for daily poultry care in many African farming systems, may exhibit different AMU patterns than men, yet gender-responsive stewardship interventions remain exceptionally rare (International Centre for Antimicrobial Resistance Solutions, n.d.). The intersectionality of these factors; how overlapping social identities and positions shape individuals' experiences, constraints, and behaviours; has only recently begun to receive empirical attention in AMR research (International Centre for Antimicrobial Resistance Solutions, n.d.).

In Tanzania, poultry farming constitutes a vital livelihood activity, contributing to household food security, income generation, and women's economic empowerment. The country's broiler sector has expanded considerably over the past decade, with production concentrated in regions such as Kilimanjaro and Mwanza, which present markedly different socioeconomic and agricultural landscapes. Kilimanjaro region, characterised by higher literacy rates, economic diversification, and relatively better access to extension services, contrasts sharply with Mwanza, where traditional farming practices, lower educational attainment, and more intensive market pressures shape poultry production. Recent initiatives, including the INIKA_OH_TZ project led by the Norwegian Veterinary Institute in partnership with Sokoine University of Agriculture, have begun to examine knowledge, attitudes, and practices regarding AMU among Tanzanian poultry farmers, with the goal of designing context-appropriate interventions (STAR-IDAZ International Research Consortium, 2025). Preliminary evidence suggests that while farmers recognise the importance of antimicrobials for disease management, their usage patterns are often driven by experiential knowledge, economic pressures, and the practical realities of accessing veterinary services rather than adherence to formal stewardship guidelines.

Despite these emerging insights, significant gaps remain in the literature. First, few studies have systematically examined how socioeconomic factors interact, rather than operate in isolation, to shape AMU practices among broiler farmers in Tanzania. The question is not simply whether education or training influences AMU, but how these factors combine with household composition, farming experience, flock size, and regional context to produce distinct usage patterns. Second, the application of theoretical frameworks capable of capturing this complexity; such as the Social Ecological Model (SEM), which situates individual behaviour within multiple levels of influence, and Intersectionality theory, which examines how overlapping social identities shape experiences and outcomes; remains underdeveloped in AMR research (International Centre for Antimicrobial Resistance Solutions, 2023). Third, while qualitative studies from other African countries have illuminated barriers to prudent AMU, comparable evidence from Tanzania's broiler sector is sparse, limiting the evidence base for targeted intervention design.

This study sought to address these gaps by examining the association between socioeconomic factors and antimicrobial usage patterns among broiler farmers in the Kilimanjaro and Mwanza regions of Tanzania. Specifically, the research aimed to: (1) compare AMU prevalence and frequency between the two regions; (2) identify socioeconomic determinants of AMU and usage frequency using binary and ordinal logistic regression; (3) explore interaction effects between key variables (education, training, farming experience, flock size, family size) to understand how combined factors influence AMU behaviours; and (4) contextualise quantitative findings through qualitative insights into farmers' experiences, constraints, and decision-making processes. As such, by applying the Social Ecological Model and Intersectionality framework, the study seeks to generate a nuanced understanding of how socioeconomic position, knowledge acquisition, and structural constraints jointly shape antimicrobial dependence in Tanzanian broiler systems. The findings aim to inform the development of context-sensitive, equity-oriented stewardship interventions that address not only farmer knowledge but also the institutional, economic, and environmental barriers to responsible antimicrobial use.

2.0 Theoretical Framework

This study is underpinned by two complementary theoretical perspectives that together provide a comprehensive lens for understanding the complex interplay between socioeconomic factors and antimicrobial use (AMU) practices among broiler farmers in Tanzania: the Social Ecological Model (SEM) and Intersectionality Theory. These frameworks are particularly well-suited to examining how individual behaviours are shaped by multiple, interacting levels of influence and how overlapping social identities create distinct experiences, constraints, and opportunities that shape farming practices and health-related decision-making.

2.2.1 The Social Ecological Model

The Social Ecological Model, originally developed by Urie Bronfenbrenner (1979) as part of his ecological systems theory of human development, posits that individual behaviour cannot be understood in isolation but must be situated within the multiple, nested environmental contexts in which people live and act. Bronfenbrenner conceptualised the environment as a series of interconnected systems; ranging from the immediate settings containing the developing person (microsystem) to the broader cultural values, economic structures, and policy environments (macrosystem); that dynamically interact to shape human development and behaviour (Bronfenbrenner, 1979). Subsequent adaptations of this model in public health research have emphasised that health behaviours are influenced by factors at multiple levels, including individual (knowledge, attitudes, skills), interpersonal (social networks, family dynamics, peer influences), organisational (institutional rules, workplace practices), community (social norms, cultural values), and policy (laws, regulations, economic structures) levels (McLeroy, Bibeau, Steckler, & Glanz, 1988).

In the context of AMU among broiler farmers, the Social Ecological Model offers a valuable framework for understanding how antimicrobial use practices emerge from the convergence of factors operating at different levels of the social and agricultural system. At the *individual level,* farmers' decisions regarding antimicrobial use are influenced by their educational attainment, knowledge about disease management, farming experience, and personal beliefs about the efficacy and necessity of antimicrobials (Caudell et al., 2020). At the *interpersonal level,* social networks, including family members, fellow farmers, and informal community advisors, shape AMU practices through information sharing, social norms, and collective decision-making processes (Jacobsen *et al.,* 2025). At the *organisational level,* access to veterinary services, availability of extension training, and the practices of agro-veterinary outlets influence farmers' ability to obtain and use antimicrobials appropriately (Goutard *et al.,* 2017). At the *community level,* regional disease pressures, cultural beliefs about animal health, and prevailing farming practices create contexts that either facilitate or constrain prudent antimicrobial use (Caudell *et al.,* 2017). Finally, at the *policy level,* regulatory frameworks governing antimicrobial access, the structure of veterinary pharmaceutical markets, and the presence or absence of national AMR action plans shape the broader environment within which farmers make decisions (Lhermie *et al.,* 2019).

The application of SEM to AMU research has gained traction in recent years, with scholars recognising that interventions targeting only individual knowledge or attitudes are unlikely to succeed if they fail to address the structural and contextual factors that shape behaviour (Goutard *et al.,* 2017). For example, training programmes that educate farmers about prudent antimicrobial use may have limited impact if farmers cannot access veterinary diagnostic services to confirm disease presence, if antibiotics remain available over-the-counter without prescription, or if economic pressures incentivise rapid, low-cost interventions over more expensive but judicious alternatives (Jacobsen *et al.,* 2025). The SEM thus directs attention to the multiple leverage points where interventions might be targeted, from individual capacity-building through to regulatory reform, and highlights the importance of aligning interventions across levels to achieve sustainable behaviour change.

2.2.2 Intersectionality Theory

While the Social Ecological Model provides a multi-level framework for understanding behaviour, Intersectionality Theory, originally developed by legal scholar Kimberlé Crenshaw (1989), offers a complementary lens for examining how overlapping social identities and positions shape individuals' experiences, constraints, and opportunities. Crenshaw introduced intersectionality to critique the tendency in anti-discrimination law and feminist theory to treat gender and race as mutually exclusive categories, arguing that Black women experience compound discrimination that cannot be understood by examining gender or race in isolation (Crenshaw, 1989). The theory posits that social identities, such as gender, class, education, ethnicity, and age, are not additive but interactive, creating unique social positions that shape access to resources, exposure to risks, and vulnerability to structural violence (Hankivsky, 2014).

In the context of agricultural health research, intersectionality has been increasingly recognised as a valuable framework for understanding how social inequalities shape farming practices, health outcomes, and responses to interventions (International Centre for Antimicrobial Resistance Solutions, n.d.). Applied to AMU among broiler farmers, intersectionality directs attention to how the convergence of gender, education, income sources, household composition, and regional location creates distinct positions that shape farmers' relationships with antimicrobials. For example, a female farmer with limited formal education, sole reliance on farm income, and residence in a region with weak veterinary infrastructure may face a fundamentally different set of constraints and incentives regarding antimicrobial use than a male farmer with secondary education, diversified income sources, and access to extension services, even if both are engaged in broiler production.

The intersectional lens is particularly important for understanding the gender dimensions of AMU in Tanzanian poultry systems. Research across sub-Saharan Africa has demonstrated that women typically assume primary responsibility for daily poultry care, including disease monitoring and medication administration, yet they often have less access than men to veterinary services, extension training, and agricultural inputs (Mugisha *et al.,* 2020; International Centre for Antimicrobial Resistance Solutions, n.d.). This gendered division of labour, combined with differential access to resources and information, may produce distinct AMU patterns among female and male farmers that are not reducible to gender alone but emerge from the intersection of gender with education, income, household structure, and regional context.

Similarly, intersectionality illuminates how education and training interact to shape AMU practices in ways that simple additive models may miss. The finding from this study that education combined with training increased, rather than decreased, AMU likelihood and frequency (the "competency paradox") can be understood through an intersectional lens: farmers occupying the intersection of "educated" and "trained" may occupy a distinct social position characterised by greater confidence in autonomous medication administration, different relationships with veterinary professionals, and differential access to pharmaceutical supply chains, all of which shape their antimicrobial practices in ways that neither education nor training alone would predict.

2.2.3 Integrating SEM and Intersectionality as a Consolidated Framework

This study integrates the Social Ecological Model and Intersectionality Theory to create a consolidated analytical framework that captures both the multi-level nature of influences on AMU and the intersecting social identities that shape farmers' positions within these levels. The integrated framework (Figure 1) conceptualises AMU practices among broiler farmers as outcomes emerging from the dynamic interaction of:

i. *Individual-level factors* (education, knowledge, beliefs, farming experience) that are themselves shaped by intersecting social identities;
ii. *Interpersonal factors* (family dynamics, social networks, gender relations within households) that are structured by intersecting positions of gender, age, and household composition;
iii. *Organisational factors* (access to veterinary services, training availability, agro-veterinary practices) that distribute resources and opportunities differently across social groups;
iv. *Community-level factors* (regional disease ecology, cultural norms, social capital) that create contexts of vulnerability or resilience that are differentially experienced based on intersecting identities; and
v. *Policy-level factors* (regulatory frameworks, market structures, national AMR strategies) that structure the broader opportunity space within which farmers operate, again with differential effects across social groups.

The integration of intersectionality with SEM addresses a limitation of traditional ecological models: their tendency to treat individuals as undifferentiated actors within levels, obscuring how social inequalities structure access to resources and exposure to risks across levels (Hankivsky, 2014). As such, by foregrounding intersectionality, the framework recognises that the "individual" at the centre of the ecological model is not generic but is positioned at the intersection of multiple social hierarchies that shape their experiences at every level of the system.

This integrated framework guides the study's analytical approach in several ways. First, it informs the selection of variables; including gender, education, income source, family size, farming experience, and regional location; as markers of intersecting social positions rather than as isolated characteristics. Second, it motivates the examination of interaction effects between variables (education × training, farming experience × flock size) as empirical manifestations of intersectional dynamics. Third, it structures the interpretation of findings by attending to how the same factor (e.g., training) may have different effects depending on farmers' positions within intersecting social hierarchies. Fourth, it informs the qualitative analysis by directing attention to how farmers themselves narrate the constraints and opportunities shaped by their multiple, overlapping identities and positions.

In doing so, the framework responds to calls in the AMR literature for research approaches capable of capturing the complexity of AMU behaviours in LMIC contexts, where structural factors, social inequalities, and individual agency interact in ways that simple linear models cannot adequately represent (Caudell *et al.,* 2020; Lhermie *et al.,* 2019). The ultimate aim is to generate insights that can inform the design of equity-oriented, context-sensitive interventions that address not only what farmers know but who they are, where they are located, and how intersecting systems of privilege and disadvantage shape their relationships with antimicrobials.

3.0 Methodology

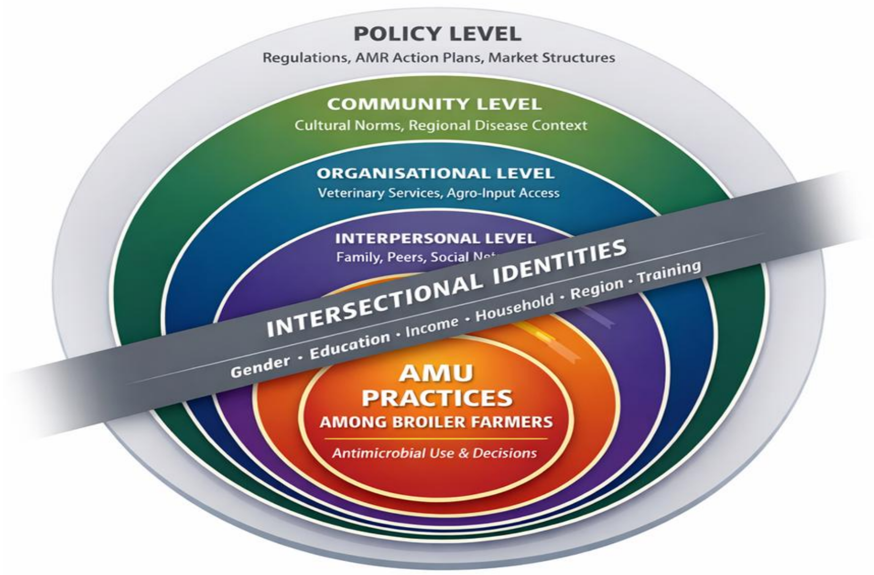
3.1 Study setting

Broiler farming constitutes a significant component of agricultural activity in Tanzania, contributing to both food security and economic development across diverse agro-ecological zones (Mdegela *et al.,* 2021). The country's poultry sector has experienced substantial growth over the past decade, driven by increasing urban demand for animal-source proteins and the recognition of poultry production as a viable livelihood strategy for smallholder farmers (Mdemu *et al.,* 2025). Within this context, Kilimanjaro and Mwanza regions present markedly contrasting socioeconomic and agricultural landscapes, rendering them ideal for comparative case study analysis.

Kilimanjaro region, located in northern Tanzania, is characterised by higher literacy rates, economic diversification, and relatively better access to agricultural extension services compared to many other parts of the country (Rabbi & Dey, 2019). The region's agricultural profile includes both large-scale and smallholder farming systems, with poultry production integrated into mixed crop-livestock enterprises. Previous research has documented evidence of high levels of antimicrobial resistance in animal populations within Kilimanjaro, underscoring the importance of understanding AMU practices in this context (Mdegela *et al.,* 2019; Mushi *et al.,* 2019). The region's proximity to veterinary service providers and relatively well-developed infrastructure may influence farmers' access to antimicrobials and veterinary advice.

In contrast, Mwanza region, situated on the shores of Lake Victoria in northwestern Tanzania, represents a different agricultural and socioeconomic environment. According to the National Agriculture Sample Census of 2019/2020,

Figure 1: Figure 1. Integrated Social Ecological–Intersectionality Framework for Understanding Antimicrobial Use (AMU) among Broiler Farmers in Tanzania



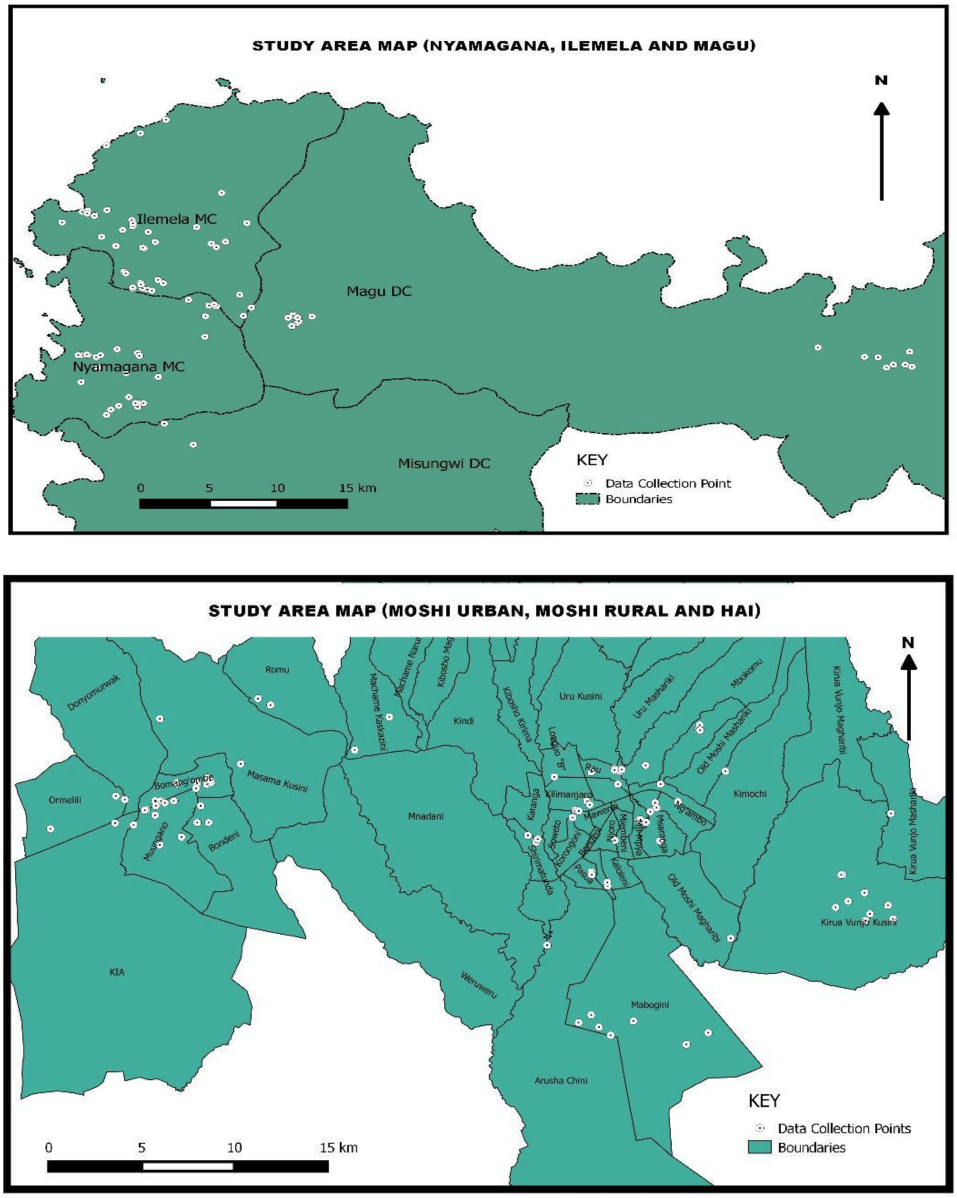
ISSN: 2619-8894 (Online), 2619- 8851 (Print)

Mwanza ranked third nationally in broiler production, with an estimated 1,028,394 birds accounting for 8.1% of the country's total broiler population (United Republic of Tanzania, 2021). This high production volume suggests intensive farming practices that may be associated with elevated antimicrobial demand and usage. The region is characterised by traditional farming practices, variable educational attainment, and more intensive market pressures shaped by its urban centres and fish-exporting economy (McKernan, 2021). Within the two regions, three districts were purposively selected based on their representativeness of broiler production systems and accessibility considerations. In Kilimanjaro Region, Moshi Municipal, Moshi Rural, and Hai districts were chosen to capture variation along the urban–rural continuum and differences in market integration. In Mwanza Region, Ilemela, Nyamagana, and Magu districts were selected to represent both peri-urban production systems serving Mwanza city and more rural farming contexts characteristic of the Lake Victoria basin. The selection of these two regions and their constituent districts enable examination of how regional socioeconomic disparities; including differences in educational attainment, gender composition of farming populations, access to veterinary services, and market integration; shape antimicrobial usage patterns among broiler farmers. This comparative approach aligns with recommendations in the literature for multi-site studies that capture contextual variation in AMU determinants (Caudell *et al.,* 2020; Mdemu *et al.,* 2025).

3.2 Study design

A cross-sectional study employing mixed methods was conducted between February and March 2024. The cross-sectional design was chosen for its appropriateness in describing the prevalence and distribution of AMU practices and examining associations with socioeconomic factors at a single point in time (Creswell & Clark, 2017). The mixed-methods approach, combining quantitative surveys with qualitative interviews, was selected to generate both breadth

Figure 2: Map Showing the Location of the Study Area. (The map was generated using QGIS version 3.24.)



of coverage and depth of understanding regarding the complex factors shaping AMU behaviours (Tashakkori & Teddlie, 2010).

The quantitative component employed a structured questionnaire to collect data on farmers' socioeconomic characteristics, farming practices, and antimicrobial usage patterns. The qualitative component comprised in-depth interviews and focus group discussions to contextualise quantitative findings, explore farmers' decision-making processes, and elucidate the structural constraints and social dynamics influencing AMU practices. This methodological triangulation enhances the validity and comprehensiveness of findings by allowing cross-verification of evidence from multiple sources and capturing both the *"what"* and the *"why"* of AMU patterns (Bryman, 2016).

3.3 Study population and sampling

The study targeted all broiler farmers who were actively keeping broiler chickens within the two weeks preceding the survey in each region. Farmers keeping fewer than 50 chickens were excluded from the study to focus on those with more established commercial operations, as very small-scale producers may exhibit fundamentally different production dynamics and AMU practices (Azabo *et al.,* 2022).

To identify eligible participants, an initial sampling frame of broiler farmers was generated in January 2024 through collaboration with multiple institutional partners. In Kilimanjaro region, the Norwegian Church Aid; a non-governmental organisation with extensive experience in agricultural development; provided access to their farmer registries and facilitated initial contacts. In both regions, local veterinary officers contributed their knowledge of active broiler farms based on routine surveillance and extension activities. This multi-source approach to sampling frame construction aimed to maximise coverage and reduce the exclusion bias that can arise from reliance on a single registry (Thompson, 2012).

The primary criterion for inclusion in the sampling frame was active engagement in broiler chicken farming with a minimum flock size of 50 birds. However, during fieldwork preparation, it became evident that some farms listed in existing registries were no longer operational due to disease outbreaks, market fluctuations, or farmers' exit from poultry production. To address this dynamic and ensure comprehensive coverage of currently active farmers, the sampling frame was iteratively revised through community engagement strategies. These included consultations with ward livestock extension officers, snowball sampling through participating farmers' networks, and community meetings where the research objectives were explained and farmers were invited to participate (Atkinson & Flint, 2001).

The final sample comprised 246 broiler farmers, with 123 respondents from each region. This sample size was determined based on considerations of statistical power for detecting meaningful differences between regions and associations between socioeconomic factors and AMU outcomes, while remaining feasible within the study's resource and time constraints. All active farmers identified through the revised sampling frame who were available and consented to participate during the data collection period were included in the study, making the sample a near-complete census of accessible broiler farmers meeting inclusion criteria in the selected districts.

3.4 Data collection tools and procedures

3.4.1 Questionnaire development

A structured questionnaire was developed for electronic data collection using the KoboToolbox platform (Hartung *et al.,* 2010). KoboToolbox was selected for its suitability in resource-constrained settings, its offline data collection capabilities, its compatibility with mobile devices, and its strong data security features. The platform enables real-time data synchronisation upon internet connectivity, reducing data entry errors and accelerating the transition from data collection to analysis.

The questionnaire was developed through an iterative process informed by a comprehensive review of the literature on AMU in livestock systems and existing survey instruments from similar studies in East Africa (Caudell *et al.,* 2017; Mdemu *et al.,* 2025). Domains covered in the questionnaire included: (1) demographic characteristics (age, gender, marital status, ethnicity, education level, family size); (2) farming characteristics (farming experience, flock size, income sources, production system); (3) antimicrobial usage (whether antimicrobials were used, frequency of use, types of antimicrobials used, sources of antimicrobials, purposes of use); (4) knowledge and attitudes regarding antimicrobials and antimicrobial resistance; and (5) access to veterinary services and training.

To ensure content validity and clarity, the questionnaire was pre-tested with five broiler farmers who were not part of the study sample during a pilot study conducted in Machame Ward and Siha District in Kilimanjaro region in January 2024. The pilot served multiple purposes: assessing question comprehensibility and relevance, evaluating the flow and length of the survey, testing the functionality of the electronic data collection tool in field conditions, and training enumerators in consistent administration procedures (Presser *et al.,* 2004). Based on feedback from pilot participants and enumerator observations, questions were reworded for clarity, response categories were refined, and skip patterns were adjusted to improve logical flow.

3.4.2 Data collection procedures

Data collection was conducted by a team of trained enumerators with experience in agricultural surveys and familiarity with the study regions. Enumerators underwent a two-day training programme covering: study objectives and ethical protocols; familiarisation with the questionnaire and KoboToolbox; techniques for building rapport with respondents; strategies for handling sensitive questions; and standardised approaches to probing and recording responses.

The survey was administered through face-to-face interviews with farmers, typically conducted at their farms or homes, depending on participant preference. Each interview lasted approximately 45–60 minutes. The face-to-face mode was chosen to accommodate variations in literacy levels, enable clarification of questions where needed, and facilitate the collection of detailed qualitative comments that could enrich quantitative responses (de Leeuw, 2005).

In addition to the structured survey, qualitative data were collected through in-depth interviews with a purposively selected subset of farmers (n = 15) and focus group discussions (n = 4, with 6–8 participants each) conducted in each region. In-depth interviews explored farmers' experiences with disease management, their decision-making processes regarding antimicrobial use, their perceptions of the benefits and risks of antimicrobials, and the constraints they face in accessing veterinary services and information. Focus group discussions brought together farmers from similar geographic areas to explore shared experiences, social norms regarding AMU, and community-level factors influencing practices (Kitzinger, 1995). All qualitative sessions were audio-recorded with participants' consent, transcribed verbatim, and translated into English for analysis where necessary.

3.4.3 Variables and measurement

The primary outcome variable was antimicrobial use (AMU), operationalised in two ways. First, as a binary variable indicating whether farmers reported using any antimicrobials in their broiler production (yes/no). Second, as an ordinal variable capturing frequency of antimicrobial use, categorised as: daily, weekly, monthly, rarely, or never. This ordinal categorisation enables examination of factors associated with more frequent versus less frequent usage patterns, recognising that occasional use may differ fundamentally from routine prophylactic or metaphylactic use in its determinants and implications (Lhermie *et al.*, 2019).

Based on the theoretical framework integrating the Social Ecological Model and Intersectionality Theory, a range of socioeconomic and demographic variables were collected as potential predictors of AMU. These included:

- *Education level:* Categorised as primary, secondary, college, or university education
- *Gender:* Male or female (as reported by participants)
- *Age:* Collected as continuous variable and categorised into five groups (18–28, 29–35, 36–45, 46–60, above 60 years)
- *Marital status:* Single, married, or widowed
- *Ethnicity/tribe:* Self-identified ethnic affiliation
- *Income source:* Categorised as farm income only, non-farm income only, or both
- *Family size:* Number of household members, categorised as less than 3, 3–5, 6–10, or above 10 members
- *Farming experience:* Years engaged in broiler farming, categorised as less than 3 years, 3–5 years, 5–10 years, or above 10 years
- *Flock size:* Number of broilers kept, categorised as less than 100, 100–500, 500–1000, or above 1000 birds
- *Training on AMU:* Whether farmers had received any formal or informal training related to antimicrobial use (yes/no)

The inclusion of interaction terms in analytical models; particularly education × training and farming experience × flock size; was informed by the intersectionality framework's emphasis on how combined social positions produce effects that differ from the sum of individual factors (Crenshaw, 1989; Hankivsky, 2014).

3.5 Data analysis

3.5.1 Quantitative data analysis

Data were downloaded from KoboToolbox and imported into R software version 4.4.1 (R Core Team, 2023) for cleaning and analysis. Prior to analysis, data were examined for inconsistencies, out-of-range values, and missing data patterns. Farmers with incomplete responses on key variables (antimicrobial use or demographic characteristics) were excluded from analysis using listwise deletion, resulting in a final analytical sample of 246 respondents.

Descriptive analysis: Categorical variables were summarised using frequencies (n) and percentages (%) overall and stratified by region. Chi-square tests (χ^2) were employed to assess regional differences in socioeconomic characteristics and AMU patterns, with statistical significance set at $p < 0.05$.

Binary logistic regression: To examine factors associated with the binary outcome of antimicrobial use (yes/no), univariate and multivariate binary logistic regression analyses were conducted. Variables showing association with AMU at $p < 0.20$ in univariate analysis were considered for inclusion in the multivariate model, following recommendations for variable selection in explanatory modelling (Hosmer, Lemeshow, & Sturdivant, 2013). The final multivariate model was built using a stepwise approach guided by the Akaike Information Criterion (AIC) and theoretical considerations. Results are presented as odds ratios (OR) with 95% confidence intervals (CI) and p-values. Model fit was assessed using the Hosmer–Lemeshow goodness-of-fit test.

Ordinal logistic regression: To examine factors associated with the frequency of antimicrobial use (ordered categories: never, rarely, monthly, weekly, daily), ordinal logistic regression was employed using the proportional odds assumption (McCullagh, 1980). The proportional odds assumption was tested using the Brant test. Results are presented as odds ratios (OR) representing the odds of being in a higher versus lower usage category for each unit increase in the predictor variable. Model fit was assessed using the likelihood ratio test comparing the full model to a null model.

Interaction effects: Based on the theoretical framework, interaction terms were constructed and tested to examine whether the effects of education, training, farming experience, and flock size on AMU were conditional on each other. Interaction terms were retained in final models where significant at $p < 0.05$ and where their inclusion improved model fit based on likelihood ratio tests.

Multicollinearity assessment: Variance Inflation Factors (VIF) were calculated for all predictors in final models to assess multicollinearity, with values exceeding 10 considered indicative of problematic collinearity (Kutner, Nachtsheim, & Neter, 2004).

3.5.2 Qualitative data analysis

Qualitative data from in-depth interviews and focus group discussions were analysed using thematic analysis following the framework approach (Ritchie & Spencer, 1994). Analysis proceeded through several stages: familiarisation with the data through repeated reading of transcripts; development of a coding framework based on a priori themes derived from the theoretical framework and emergent themes from the data; systematic coding of all transcripts using NVivo software; charting of coded data into thematic matrices; and interpretation of patterns, associations, and explanations within and across themes (Gale *et al.,* 2013).

Thematic analysis was conducted by two researchers independently, with discrepancies resolved through discussion and consensus. Themes were organised around the multi-level factors of the Social Ecological Model; individual, interpersonal, organisational, community, and policy; and examined for how they intersected with gender, education, and other social positions. Illustrative quotations are presented in the results to contextualise and enrich quantitative findings, with participant identifiers (region, gender) provided to situate quotations within farmers' social locations.

3.5.3 Integration of quantitative and qualitative data

Integration of quantitative and qualitative findings occurred at the interpretation stage, following a weaving approach where quantitative results and qualitative themes are presented together within thematic sections (Fetters, Curry, & Creswell, 2013). This integration enables quantitative patterns to be illuminated by qualitative insights into the mechanisms, meanings, and contexts underlying observed associations, while qualitative findings are given broader evidentiary support through their alignment with quantitative patterns.

3.6 Ethical considerations

3.6.1 Ethical approval

This study received ethical approval from the Sokoine University of Agriculture (SUA), granted by the Directorate of Postgraduate Studies, Research, Technology Transfer, and Consultancy. The Institutional Review Board (IRB) approval reference number was *SUA/ADM/R.1/8/1152*. Following this approval, a research permit was sought from the President's Office of Regional Administration and Local Government (PO-RALG) to authorise the study's conduct in Kilimanjaro and Mwanza regions. The permit was officially granted under registration number *FB.222/264/01D/20*. This two-tiered approval process, institutional ethical review followed by national research permitting, complies with Tanzanian regulations governing research involving human participants (Kabululu *et al.,* 2020).

3.6.2 Informed consent

Informed consent was obtained from each participating broiler farmer following principles of voluntary participation, full information disclosure, and comprehension (World Medical Association, 2013). Farmers were provided with detailed information about the study's objectives, procedures, potential risks, and anticipated benefits in Swahili, the local language. Information was conveyed orally and supplemented with written information sheets for those who could read.

Consent was documented through written signatures or thumbprints for literate and non-literate participants respectively. In cases where participants were uncomfortable providing written consent, a documented consideration in Tanzanian research contexts where signatures may be associated with formal obligations, verbal consent was accepted in the presence of an independent witness who co-signed the consent form (Kabululu *et al.,* 2020). Participants were informed of their right to withdraw from the study at any point without consequence and to decline answering any specific questions.

3.6.3 Confidentiality and anonymity

To protect participant privacy, all data were anonymised at the point of collection through assignment of unique study identifiers. Personal identifiers (names, specific locations, contact information) were stored separately from survey data in password-protected files accessible only to the principal investigator. In reports and publications, no individual identifying information is presented, and quotations are attributed using general descriptors (e.g., "female farmer, Kilimanjaro") that provide context without compromising anonymity.

Data were stored on secure university servers with access restricted to authorised research team members. Electronic data collection using KoboToolbox incorporated encryption during transmission and storage, and mobile devices used for data collection were password-protected. These measures align with best practices for protecting participant confidentiality in digital data collection environments.

3.6.4 Community engagement

Beyond individual consent, the study incorporated community-level engagement strategies to ensure that research activities were understood and accepted within the study communities. Prior to data collection, meetings were held with local government leaders, veterinary officers, and community representatives to explain the study's purpose, address concerns, and seek their support in facilitating farmer participation. This community-engaged approach recognises that individual consent operates within broader social contexts and that community endorsement can enhance both ethical conduct and research quality (Tindana *et al.,* 2007).

4.0 RESULTS AND DISCUSSION

4.1 Socio-demographic characteristics of respondents

A total of 246 broiler farmers participated in the study, with 123 respondents from each of the two regions (Kilimanjaro and Mwanza). Table 1 presents the socio-demographic characteristics of respondents stratified by region, revealing notable variations in the composition of farming populations across the two study areas. These characteristics represent individual-level factors within the Social Ecological Model (SEM) that shape farmers' positions within broader agricultural systems and their subsequent antimicrobial use behaviours (Bronfenbrenner, 1979).

4.1.1 Gender distribution

Gender distribution differed significantly between regions ($\chi^2 = 4.988$, df = 1, p = 0.026). In Kilimanjaro, female farmers constituted the majority (74.8%, n = 93), while males represented 25.2% (n = 31). In Mwanza, although females still outnumbered males, the gender gap was narrower, with females comprising 61.8% (n = 76) and males 38.2% (n = 47). In general, 68.4% (n = 169) of respondents across both regions were female, underscoring women's predominant role in broiler production in these contexts. This gender distribution aligns with broader patterns in sub-Saharan African poultry systems, where women typically assume primary responsibility for smallholder poultry management, particularly for daily care and disease monitoring activities (Mugisha *et al.,* 2020; Dumas *et al.,* 2018). From an intersectionality perspective (Crenshaw, 1989), this gendered division of labour positions women at the front line of antimicrobial administration decisions, a theme that emerged strongly in qualitative findings and has important implications for understanding AMU patterns through the lens of overlapping social identities (International Centre for Antimicrobial Resistance Solutions, n.d.).

4.1.2 Age distribution

Age distribution was relatively similar across regions ($\chi^2 = 1.450$, df = 4, p = 0.835), with the majority of farmers (58.9%) falling within the 36–60 year age bracket (Table 1). The largest age group in both regions consisted of farmers aged 46–60 years (Kilimanjaro: 34.7%, n = 43; Mwanza: 28.5%, n = 35), followed by those aged 36–45 years (Kilimanjaro: 25.0%, n = 31; Mwanza: 28.5%, n = 35). Farmers aged 18–28 years constituted only 9.3% (n = 23) of the total sample, suggesting limited youth participation in broiler farming. Farmers above 60 years represented 17.8% (n = 44) of respondents, indicating significant engagement of older farmers in the sector.

4.1.3 Marital status

Marital status patterns did not differ significantly between regions ($\chi^2 = 2.198$, df = 2, p = 0.333) (Table 1). Across both regions, married farmers predominated (78.0%, n = 192), with slightly higher rates in Mwanza (81.3%, n = 100) compared to Kilimanjaro (74.8%, n = 92). Single respondents constituted 15.4% (n = 38) overall, while widowed individuals accounted for 6.5% (n = 16). The higher proportion of widowed farmers in Kilimanjaro (8.1%, n = 10) compared to Mwanza (4.9%, n = 6) may reflect regional differences in household structure, with implications for household labour availability and decision-making dynamics at the interpersonal level of the SEM.

4.1.4 Ethnic composition

Ethnic composition differed markedly between regions ($\chi^2 = 181.762$, df = 3, p < 0.001), reflecting the distinct ethnic geographies of Tanzania. In Kilimanjaro, the Chaga tribe predominated (64.2%, n = 79), followed by the Pare (24.4%, n = 30). In Mwanza, the Sukuma tribe constituted the overwhelming majority (87.8%, n = 108), consistent with the Sukuma's status as Tanzania's largest ethnic group and their dominance in the Lake Victoria zone (Brandström, 1990). Other ethnic groups constituted a minor percentage overall (4.1%, n = 10), primarily concentrated in Kilimanjaro. These ethnic differences, viewed through an intersectionality lens, may shape farming practices, social networks, and information-sharing pathways that influence AMU at the community level of the SEM (Hankivsky, 2014).

4.1.5 Educational attainment

Educational levels varied significantly across regions (χ^2 = 11.097, df = 3, p = 0.011), with Mwanza respondents reporting higher educational attainment than their Kilimanjaro counterparts (Table 1). While primary education was more common in Kilimanjaro (39.0%, n = 48) than in Mwanza (21.1%, n = 26), secondary education was reported by 39.8% (n = 49) of Kilimanjaro farmers and 43.9% (n = 54) of Mwanza farmers. College education was substantially more prevalent in Mwanza (34.1%, n = 42) compared to Kilimanjaro (20.3%, n = 25). University graduates were rare in both regions, comprising only 0.8% (n = 2) of the total sample. These regional differences in educational profiles, situated at the individual level of the SEM, may influence farmers' access to information, engagement with extension services, and decision-making regarding antimicrobial use (Caudell *et al.,* 2020; Mdemu *et al.,* 2025).

4.1.6 Income sources

Farm income was the primary source of earnings for most respondents (61.0%, n = 150), with slightly higher reliance on farm income in Mwanza (64.2%, n = 79) compared to Kilimanjaro (57.7%, n = 71), though this difference was not statistically significant (χ^2 = 1.101, df = 2, p = 0.577) (Table 1). Non-farm income contributed to household livelihoods for 35.4% (n = 87) of respondents overall, while only 3.7% (n = 9) reported earning from both farm and non-farm sources. The predominance of farm income suggests that broiler production constitutes a critical livelihood activity for most households, potentially increasing farmers' risk aversion and their willingness to use antimicrobials as insurance against production losses (Lhermie *et al.,* 2019). This economic dimension operates at the intersection of individual and community levels within the SEM framework.

4.1.7 Family size

Household size remained relatively consistent across regions (χ^2 = 1.586, df = 3, p = 0.663). Most respondents reported

Table 1: Socio-demographic characteristics of respondents by region (n = 246)

Characteristic	Category	Kilimanjaro (n = 123)	Mwanza (n = 123)	Total (N = 246)	χ^2	df	p-value
		n (%)	n (%)	n (%)			
Gender	Female	93 (75.6)	76 (61.8)	169 (68.7)	4.988	1	**0.026**
	Male	30 (24.4)	47 (38.2)	77 (31.3)			
Age category (years)	18–28	10 (8.1)	13 (10.6)	23 (9.3)	1.450	4	0.835
	29–35	18 (14.6)	18 (14.6)	36 (14.6)			
	36–45	31 (25.2)	35 (28.5)	66 (26.8)			
	46–60	43 (35.0)	35 (28.5)	78 (31.7)			
	>60	21 (17.1)	22 (17.9)	43 (17.5)			
Marital status	Single	21 (17.1)	17 (13.8)	38 (15.4)	2.198	2	0.333
	Married	92 (74.8)	100 (81.3)	192 (78.0)			
	Widowed	10 (8.1)	6 (4.9)	16 (6.5)			
Ethnicity	Chaga	79 (64.2)	5 (4.1)	84 (34.1)	181.762	3	**<0.001**
	Pare	30 (24.4)	10 (8.1)	40 (16.3)			
	Sukuma	4 (3.3)	108 (87.8)	112 (45.5)			
	Other	10 (8.1)	0 (0.0)	10 (4.1)			
Education level	Primary	48 (39.0)	26 (21.1)	74 (30.1)	11.097	3	**0.011**
	Secondary	49 (39.8)	54 (43.9)	103 (41.9)			
	College	25 (20.3)	42 (34.1)	67 (27.2)			
	University	1 (0.8)	1 (0.8)	2 (0.8)			
Primary income source	Farm only	71 (57.7)	79 (64.2)	150 (61.0)	1.101	2	0.577
	Non-farm only	47 (38.2)	40 (32.5)	87 (35.4)			
	Both	5 (4.1)	4 (3.3)	9 (3.7)			
Family size (members)	<3	14 (11.4)	11 (8.9)	25 (10.2)	1.586	3	0.663
	3–5	62 (50.4)	66 (53.7)	128 (52.0)			
	6–10	46 (37.4)	43 (35.0)	89 (36.2)			
	>10	1 (0.8)	3 (2.4)	4 (1.6)			
Farming experience (years)	<3	31 (25.2)	26 (21.1)	57 (23.2)	1.842	3	0.606
	3–5	42 (34.1)	37 (30.1)	79 (32.1)			
	5–10	28 (22.8)	36 (29.3)	64 (26.0)			
	>10	22 (17.9)	24 (19.5)	46 (18.7)			
Flock size (birds)	<100	20 (16.3)	17 (13.8)	37 (15.0)	1.082	3	0.781
	100–500	90 (73.2)	89 (72.4)	179 (72.8)			
	500–1000	11 (8.9)	13 (10.6)	24 (9.8)			
	>1000	2 (1.6)	4 (3.3)	6 (2.4)			

Note: Percentages are column percentages. p-values from Pearson's chi-square tests. Statistically significant differences (p < 0.05) are indicated in bold. Percentages may not sum to 100% due to rounding having 3–5 household members (52.0%, n = 128), followed by 6–10 members (36.2%, n = 89) (Table 1). Smaller households with fewer than 3 members constituted 10.2% (n = 25), while very large households with more than 10 members were rare (1.6%, n = 4). The predominance of medium-sized households reflects typical family structures in rural Tanzania and has implications for labour availability for poultry management tasks (Mdemu *et al.,* 2025). Family size, as an interpersonal-level factor within the SEM, emerged as a significant predictor of AMU frequency in regression analyses.

4.1.8 Farming experience

Farming experience was distributed across categories without significant regional variation ($\chi^2 = 1.842$, df = 3, p = 0.606) (Table 1). The largest proportion of farmers had 3–5 years of broiler farming experience (32.1%, n = 79), followed by 5–10 years (26.0%, n = 64), less than 3 years (23.2%, n = 57), and above 10 years (18.7%, n = 46). The relatively even distribution across experience categories enables examination of how experience, as an individual-level characteristic, shapes AMU practices and interacts with other factors such as flock size (Caudell *et al.,* 2017).

4.1.9 Flock size

Flock size distribution was largely similar across regions ($\chi^2 = 1.082$, df = 3, p = 0.781), with most farmers keeping 100–500 broilers (72.8%, n = 179) (Table 1). Smaller flocks of fewer than 100 birds were maintained by 15.0% (n = 37) of farmers, while flocks of 500–1000 birds were kept by 9.8% (n = 24). Only 2.4% (n = 6) of farmers operated flocks exceeding 1000 birds, indicating that large-scale commercial operations remain uncommon in both regions. The concentration of farmers in the 100–500 bird category suggests that broiler production is characterised by medium-scale operations, which may face different disease pressures and economic incentives compared to very small or very large enterprises (Azabo *et al.,* 2022). Flock size, operating at the organisational level of the SEM, demonstrated significant interaction effects with farming experience in predicting AMU frequency.

4.2 Gender-disaggregated demographic characteristics

Table 2 presents demographic characteristics disaggregated by both region and gender, revealing important intra-regional gender dynamics that may influence AMU practices through the intersectionality lens (Crenshaw, 1989; Hankivsky, 2014). These patterns illustrate how gender intersects with other social positions; age, marital status, income sources, and education; to shape farmers' structural positions and, consequently, their antimicrobial use behaviours.

In Kilimanjaro, female farmers were concentrated in older age categories, with 38.0% (n = 35) aged 46–60 years and 28.3% (n = 26) aged 36–45 years. Male farmers in Kilimanjaro were more evenly distributed across age categories, with 32.3% (n = 10) aged 29–35 years and 25.8% (n = 8) aged 46–60 years. In Mwanza, similar patterns emerged: female farmers were predominantly aged 46–60 years (33.8%, n = 26) and 36–45 years (31.2%, n = 24), while male farmers showed greater representation in younger age groups, with 21.7% (n = 10) aged 18–28 years.

Marital status patterns revealed that married women constituted the majority in both regions (Kilimanjaro: 73.9%, n = 68; Mwanza: 85.7%, n = 66), while widowed farmers were exclusively female. This pattern reflects gender differences in remarriage and household headship documented elsewhere in sub-Saharan Africa (Dumas *et al.,* 2018). Male farmers in both regions showed higher proportions of single individuals compared to their female counterparts, suggesting different life-course trajectories into farming.

Income sources exhibited gendered patterns: in Mwanza, 71.7% (n = 33) of male farmers relied solely on farm income compared to 59.7% (n = 46) of female farmers, while female farmers reported higher reliance on non-farm income (36.4%, n = 28) than males (26.1%, n = 12). This pattern may reflect women's engagement in multiple livelihood activities, including small-scale trading, to diversify household income and manage risk (Mdemu *et al.,* 2025). From an intersectionality perspective, these gendered economic positions shape differential access to resources and decision-making power, influencing AMU practices at the intersection of gender and income source.

Flock size distribution was relatively similar across gender within regions, though in Kilimanjaro, a higher proportion of female farmers (10.9%, n = 10) maintained flocks of 500–1000 birds compared to male farmers (3.2%, n = 1). Educational attainment showed that in both regions, female farmers were more likely to have secondary education (Kilimanjaro: 40.2%, n = 37; Mwanza: 46.8%, n = 36) and less likely to have college education compared to male farmers, though the differences were not pronounced.

Table 2: Gender-disaggregated demographic characteristics by region (n = 246)

Characteristic	Category	Kilimanjaro		Mwanza	
		Male (n = 30)	Female (n = 93)	Male (n = 47)	Female (n = 76)
		n (%)	n (%)	n (%)	n (%)
Age category (years)	18–28	5 (16.7)	5 (5.4)	10 (21.3)	3 (3.9)
	29–35	10 (33.3)	7 (7.5)	7 (14.9)	10 (13.2)
	36–45	5 (16.7)	26 (28.0)	11 (23.4)	24 (31.6)
	46–60	8 (26.7)	35 (37.6)	10 (21.3)	26 (34.2)
	>60	2 (6.7)	20 (21.5)	9 (19.1)	13 (17.1)
Marital status	Single	7 (23.3)	14 (15.1)	12 (25.5)	5 (6.6)
	Married	23 (76.7)	69 (74.2)	35 (74.5)	65 (85.5)
	Widowed	0 (0.0)	10 (10.8)	0 (0.0)	6 (7.9)
Primary income source	Farm only	19 (63.3)	52 (55.9)	33 (70.2)	46 (60.5)
	Non-farm only	9 (30.0)	38 (40.9)	12 (25.5)	28 (36.8)
	Both	2 (6.7)	3 (3.2)	2 (4.3)	2 (2.6)
Flock size (birds)	<100	6 (20.0)	14 (15.1)	8 (17.0)	9 (11.8)
	100–500	22 (73.3)	68 (73.1)	33 (70.2)	56 (73.7)
	500–1000	1 (3.3)	10 (10.8)	5 (10.6)	8 (10.5)
	>1000	1 (3.3)	1 (1.1)	1 (2.1)	3 (3.9)
Family size (members)	<3	6 (20.0)	8 (8.6)	5 (10.6)	6 (7.9)
	3–5	15 (50.0)	47 (50.5)	21 (44.7)	45 (59.2)
	6–10	9 (30.0)	37 (39.8)	19 (40.4)	24 (31.6)
	>10	0 (0.0)	1 (1.1)	2 (4.3)	1 (1.3)
Education level	Primary	12 (40.0)	36 (38.7)	12 (25.5)	14 (18.4)
	Secondary	10 (33.3)	39 (41.9)	19 (40.4)	35 (46.1)
	College	7 (23.3)	18 (19.4)	15 (31.9)	26 (34.2)
	University	1 (3.3)	0 (0.0)	1 (2.1)	1 (1.3)

Note: Percentages are column percentages within each region-gender subgroup.

4.3 Regional comparison of antimicrobial use prevalence and frequency

Table 3 presents the comparison of antimicrobial use prevalence and frequency between Kilimanjaro and Mwanza regions, revealing significant regional disparities that align with the SEM's emphasis on contextual factors shaping behaviour at community and policy levels (Bronfenbrenner, 1979; McLeroy *et al.,* 1988).

4.3.1 Antimicrobial use prevalence

Antimicrobial use prevalence was significantly higher in Mwanza compared to Kilimanjaro ($\chi^2 = 10.5$, df = 1, $p < 0.001$). In Mwanza, 91.1% (n = 112) of farmers reported using antimicrobials in their broiler production, compared to 81.3% (n = 100) in Kilimanjaro. Conversely, the proportion of farmers who never used antimicrobials was more than twice as high in Kilimanjaro (18.7%, n = 23) as in Mwanza (8.9%, n = 11). This regional difference suggests that farmers in Mwanza face greater disease pressure, have different access to antimicrobials, or operate under production systems that necessitate more frequent antimicrobial intervention (Caudell *et al.,* 2017; Mdemu *et al.,* 2025). The higher AMU prevalence in Mwanza may also reflect the region's ranking as the third-largest broiler producer nationally, with associated intensification pressures that drive antimicrobial dependence (United Republic of Tanzania, 2021).

4.3.2 Antimicrobial use frequency

Frequency of antimicrobial use also differed significantly between regions ($\chi^2 = 56.3$, df = 4, p = 0.04). Daily antimicrobial use was reported by 35.0% (n = 43) of farmers in Mwanza compared to 29.3% (n = 36) in Kilimanjaro. Weekly use showed a more pronounced disparity: 23.6% (n = 29) of Mwanza farmers reported weekly antimicrobial application versus 14.6% (n = 18) in Kilimanjaro. Monthly use was relatively similar between regions (Mwanza: 14.6%, n = 18; Kilimanjaro: 13.0%, n = 16). Rare use was more common in Kilimanjaro (24.4%, n = 30) than in Mwanza (17.9%, n = 22), while never use was, as noted, substantially higher in Kilimanjaro.

The concentration of Mwanza farmers in daily and weekly usage categories suggests more intensive reliance on antimicrobials, potentially reflecting differences in production intensity, disease ecology, or access to alternative disease prevention strategies (Lhermie et al., 2019). These findings align with ethnographic research from northern Tanzania showing that farmers in commercially oriented production systems often employ antimicrobials intensively to manage disease risks and protect economic investments (Caudell *et al.,* 2017). From an SEM perspective, these regional differences operate at the community level, shaped by local disease pressures, market integration, and the availability of veterinary infrastructure.

Table 3: Antimicrobial use prevalence and frequency by region (n = 246)

Variable	Category	Kilimanjaro (n = 123)	Mwanza (n = 123)	Total (N = 246)	χ²	df	p-value
		n (%)	n (%)	n (%)			
Antimicrobial use	No	23 (18.7)	11 (8.9)	34 (13.8)	10.5	1	<0.001
	Yes	100 (81.3)	112 (91.1)	212 (86.2)			
Frequency of use	Daily	36 (29.3)	43 (35.0)	79 (32.1)	56.3	4	0.04
	Weekly	18 (14.6)	29 (23.6)	47 (19.1)			
	Monthly	16 (13.0)	18 (14.6)	34 (13.8)			
	Rarely	30 (24.4)	22 (17.9)	52 (21.1)			
	Never	23 (18.7)	11 (8.9)	34 (13.8)			

Note: p-values from Pearson's chi-square tests. Statistically significant differences (p < 0.05) are indicated in bold.

4.4 Antimicrobial use frequency by socioeconomic factors

Table 4 presents the frequency of antimicrobial use disaggregated by key socioeconomic factors, revealing patterns that contextualise the regression analyses that follow and illustrate the intersectionality framework's emphasis on how overlapping social positions shape practices (Crenshaw, 1989; Hankivsky, 2014).

4.4.1 Education level

Among farmers reporting daily antimicrobial use, those with secondary education constituted the largest group (40.5%, n = 32), followed by those with primary education (31.6%, n = 25) and college education (27.8%, n = 22). Notably, among farmers who never used antimicrobials, those with primary education were overrepresented (44.1%, n = 15) compared to their representation in the daily use category, while college-educated farmers were substantially underrepresented among never-users (11.8%, n = 4). This pattern suggests a positive association between educational attainment and antimicrobial use, consistent with findings that more educated farmers may have greater access to pharmaceutical markets and confidence in medication administration (Alhaji & Isola, 2018; Mdemu *et al.,* 2025). However, as the regression analyses will show, this relationship is complicated by interaction effects with training, illustrating the intersectionality principle that education does not operate in isolation but combines with other social positions to shape outcomes.

4.4.2 Gender

Female farmers demonstrated higher frequencies of antimicrobial use across all usage categories. Among daily users, females constituted 67.1% (n = 53) compared to 32.9% (n = 26) males. This pattern persisted across weekly (females: 66.0%, n = 31; males: 34.0%, n = 16), monthly (females: 76.5%, n = 26; males: 23.5%, n = 8), and rare use categories (females: 59.6%, n = 31; males: 40.4%, n = 21). Among never-users, females were also overrepresented (82.4%, n = 28) relative to their overall sample proportion (68.7%), suggesting a bifurcated pattern where women are more likely to be either frequent users or never-users, potentially reflecting different positions within poultry production systems (Mugisha *et al.,* 2020).

Qualitative insights illuminate this pattern through the intersectionality lens. A female farmer from Boma Ng'ombe in Kilimanjaro explained:

> *"Women are more involved in daily poultry care, so they often decide when and what medicine to use. We see the birds every day, multiple times a day. When one looks sick, we act quickly because losing even one bird affects our household income."* (Female farmer, Kilimanjaro, 2024)

Conversely, a male farmer from the same region noted:

> *"I rely on my wife to tell me when something is wrong with the chickens. She manages them day-to-day. If she says they need medicine, I will go and buy it, but she is the one who notices first."* (Male farmer, Kilimanjaro, 2024)

These narratives suggest that women's proximity to daily flock management, a product of gendered labour divisions at the interpersonal level of the SEM, positions them as primary decision-makers regarding antimicrobial administration, while men's roles may be more focused on procurement and financial aspects of medication access. This finding aligns with research highlighting how gender and social inequities shape AMR vulnerabilities in livestock systems (International Centre for Antimicrobial Resistance Solutions, n.d.).

4.4.3 Age

Age patterns in antimicrobial use frequency showed that farmers aged 46–60 years were the largest group across most usage categories, comprising 26.6% (n = 21) of daily users, 31.9% (n = 15) of weekly users, 41.2% (n = 14) of monthly users, and 34.6% (n = 18) of rare users. Farmers aged 36–45 years also featured prominently across categories. Younger farmers (18–28 years) constituted smaller proportions of users, potentially reflecting their lower representation in the farming population overall.

4.4.4 Income source

Farmers relying solely on farm income demonstrated the highest frequencies of antimicrobial use across all categories, comprising 54.4% (n = 43) of daily users, 59.6% (n = 28) of weekly users, 64.7% (n = 22) of monthly users, and 63.5% (n = 33) of rare users. Among never-users, farm-only income farmers constituted 70.6% (n = 24). This pattern suggests that farmers whose livelihoods depend entirely on farming may be more likely to use antimicrobials, either frequently or not at all, compared to those with diversified income sources, reflecting the economic trade-offs inherent in agricultural antimicrobial use (Lhermie *et al.,* 2019).

A farmer from Mvuleni, Mwanza, articulated the economic logic driving antimicrobial use:

> *"If chickens die, my family suffers. I have no other income—just these birds. So, I use medicine quickly, even before confirming the disease. It is better to spend money on medicine than to lose everything."* (Male farmer, Mwanza, 2024)

This quotation illustrates how economic precarity and dependence on farm income, an individual-level factor intersecting with broader economic structures at the policy level of the SEM, can drive preventive or metaphylactic antimicrobial use, even in the absence of confirmed disease (Caudell *et al.,* 2020). This finding resonates with ethnographic research from Tanzania showing that antibiotics are often used to protect return on investment in commercially oriented livestock production (Caudell *et al.,* 2017).

antimicrobials compared to untrained farmers (OR = 0.044, 95% CI: 0.004–0.458, p = 0.011). This substantial protective effect underscores the potential of capacity-building interventions to reduce antimicrobial dependence, consistent with findings from other LMIC contexts where training programmes have been shown to promote more judicious antimicrobial use (Goutard *et al.,* 2017; Caudell *et al.,* 2020). Within the SEM framework, training operates at the organisational level, representing a modifiable intervention point for antimicrobial stewardship.

Qualitative data illuminate how training shapes farmers' practices. A farmer from Newland, Kilimanjaro, explained:

> *"Before the training, I would use antibiotics for everything, if chickens looked tired, if they weren't eating, even if I just thought disease might come. After training, I learned about hygiene, vaccination, and biosecurity. Now I focus more on prevention, and I only use antibiotics when the vet says it's necessary."* (Female farmer, Kilimanjaro, 2024)

However, qualitative findings also revealed that training availability is limited, reflecting a gap at the organisational

Table 4: Frequency of antimicrobial use by socioeconomic factors (n = 246)

Characteristic	Category	Daily (n = 79)	Weekly (n = 47)	Monthly (n = 34)	Rarely (n = 52)	Never (n = 34)
		n (%)	n (%)	n (%)	n (%)	n (%)
Education level	Primary	25 (31.6)	7 (14.9)	11 (32.4)	16 (30.8)	15 (44.1)
	Secondary	32 (40.5)	25 (53.2)	15 (44.1)	18 (34.6)	13 (38.2)
	College	22 (27.8)	15 (31.9)	8 (23.5)	18 (34.6)	4 (11.8)
	University	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (5.9)
Gender	Male	26 (32.9)	16 (34.0)	8 (23.5)	21 (40.4)	6 (17.6)
	Female	53 (67.1)	31 (66.0)	26 (76.5)	31 (59.6)	28 (82.4)
Age category (years)	18–28	10 (12.7)	6 (12.8)	1 (2.9)	3 (5.8)	3 (8.8)
	29–35	13 (16.5)	3 (6.4)	3 (8.8)	9 (17.3)	8 (23.5)
	36–45	20 (25.3)	15 (31.9)	11 (32.4)	12 (23.1)	8 (23.5)
	46–60	21 (26.6)	15 (31.9)	14 (41.2)	18 (34.6)	10 (29.4)
	>60	15 (19.0)	8 (17.0)	5 (14.7)	10 (19.2)	5 (14.7)
Primary income source	Farm only	43 (54.4)	28 (59.6)	22 (64.7)	33 (63.5)	24 (70.6)
	Non-farm only	34 (43.0)	19 (40.4)	10 (29.4)	14 (26.9)	10 (29.4)
	Both	2 (2.5)	0 (0.0)	2 (5.9)	5 (9.6)	0 (0.0)

Note: Percentages are column percentages within each usage frequency category.

4.5 Factors associated with antimicrobial use: Binary logistic regression

Table 5 presents the results of binary logistic regression analysis examining factors associated with the likelihood of antimicrobial use (yes/no). The Hosmer–Lemeshow goodness-of-fit test indicated that the model fitted the data well (χ^2 = 8.55, df = 8, p = 0.382), confirming no evidence of poor fit (Hosmer, Lemeshow, & Sturdivant, 2013). Variance Inflation Factors (VIF) were below the threshold of 10 for all predictors, indicating no problematic multicollinearity.

4.5.1 Training as a protective factor

Training emerged as the strongest predictor of antimicrobial use. Farmers who had received training related to antimicrobial use had 95.6% lower odds of using

in Buswelu, Mwanza, noted:

> *"We rarely receive training on proper use of antibiotics. The last training I remember was maybe three years ago, and it was very short. Most of what we know comes from other farmers or the agro-vet shop."* (Female farmer, Mwanza, 2024)

This gap between the demonstrated effectiveness of training and its limited availability represents a critical implementation challenge for antimicrobial stewardship in Tanzanian broiler systems.

4.5.2 Interaction between education & training

A significant interaction effect was observed between education level and training (OR = 4.01, 95% CI: 1.117–18.361, p = 0.048). This positive interaction indicates that the effect of training on antimicrobial use is conditional on education level: among farmers with higher education, training was associated with increased, rather than decreased, odds of antimicrobial use.

This finding, which we term the "competency paradox," suggests that educated farmers who receive training may develop greater confidence in their ability to administer antimicrobials appropriately, potentially leading to increased rather than decreased use. This interaction effect illustrates the intersectionality principle that social positions do not operate additively but interact to produce unique outcomes (Crenshaw, 1989; Hankivsky, 2014). As a male farmer from Mwanza with secondary education and training explained:

> *"After training, I understand which antibiotics work for which conditions. I feel confident to treat my birds myself rather than waiting for a vet who might take days to arrive. I know the doses now."* (Male farmer, Mwanza, 2024)

This quotation illustrates how training, when combined with formal education, may foster autonomous medication practices that increase rather than decrease overall antimicrobial use, highlighting the need for stewardship programmes that address not only knowledge but also the structural constraints, such as limited veterinary access, that drive self-medication.

4.5.3 Non-significant predictors

Education level alone (β = 0.221; OR = 1.25; p = 0.449), farming experience (β = −0.368; OR = 0.69; p = 0.302), family size (β = −0.466; OR = 0.63; p = 0.121), and the interaction of farming experience with flock size (β = 0.162; OR = 1.18; p = 0.269) were not statistically significant predictors of antimicrobial use in the binary model. The non-significance of these individual factors, in contrast to the significant interaction effects, reinforces the importance of examining how factors combine rather than operate in isolation, a core tenet of both the SEM and intersectionality frameworks.

antimicrobial use (ordered categories: never, rarely, monthly, weekly, daily). The proportional odds assumption was tested and satisfied. The likelihood-ratio test indicated that the full model fitted significantly better than the null model (LR χ^2 = 20.27, df = 6, p = 0.002), confirming the model's explanatory utility.

4.6.1 Training and frequency of use

Consistent with the binary model, training significantly reduced the likelihood of more frequent antimicrobial use (OR = 0.149, 95% CI: 0.028–0.780, p = 0.024). Farmers who had received training had 85.1% lower odds of being in a higher versus lower usage frequency category, reinforcing the protective effect of training against intensive antimicrobial reliance. This finding, situated at the organisational level of the SEM, underscores the importance of capacity-building interventions for promoting more judicious antimicrobial practices (Goutard *et al.,* 2017).

4.6.2 Family size as a protective factor

Family size emerged as a significant protective factor against frequent antimicrobial use (OR = 0.599, 95% CI: 0.424–0.847, p = 0.0037). For each unit increase in family size category, the odds of being in a higher usage frequency category decreased by 40.1%. This inverse relationship suggests that farmers with larger households may adopt more labour-intensive preventive practices or face financial constraints that limit frequent antimicrobial purchasing, or alternatively, that larger families enable task diversification that reduces disease pressure through improved hygiene and management.

Qualitative data clarify this finding. A farmer from Buswelu, Mwanza, explained:

> *"With many family members helping, we maintain cleanliness better. The children help with cleaning the house, my wife monitors the birds during the day, and I manage the feeding. Because we have many hands, diseases are less common, so we don't need medicine as often."* (Male farmer, Mwanza, 2024)

Table 5: Binary logistic regression analysis of factors associated with antimicrobial use (n = 246)

Variable	β	SE	Wald χ^2	OR	95% CI	p-value	VIF
(Intercept)	2.787	1.012	7.58	16.24	2.38–132.21	0.006	–
Education level	0.221	0.292	0.57	1.25	0.71–2.24	0.449	1.26
Farming experience	−0.368	0.357	1.06	0.69	0.34–1.39	0.302	3.64
Training (received)	−3.127	1.234	6.42	***0.044***	***0.004–0.458***	***0.011***	7.25
Family size	−0.466	0.300	2.41	0.63	0.34–1.12	0.121	1.04
Education × Training	1.389	0.703	3.90	***4.01***	***1.12–18.36***	***0.048***	6.87
Experience × Flock size	0.162	0.147	1.22	1.18	0.89–1.58	0.269	3.66

Note: OR = Odds Ratio; CI = Confidence Interval; VIF = Variance Inflation Factor. Model fit: Hosmer–Lemeshow χ^2 = 8.55, df = 8, p = 0.382. Statistically significant predictors (p < 0.05) are indicated in bold.

4.6 Factors associated with antimicrobial use frequency: Ordinal logistic regression

Table 6 presents the results of ordinal logistic regression analysis examining factors associated with the frequency of

This quotation illustrates how family size, as an interpersonal-level factor within the SEM, shapes the capacity for disease prevention through labour allocation, reducing the perceived need for frequent antimicrobial intervention.

4.6.3 Interaction effects in frequency model

Two interaction terms significantly influenced antimicrobial use frequency. First, the interaction of education and training significantly increased usage frequency (OR = 2.20, 95% CI: 1.014–4.776, p = 0.046). This finding replicates the "competency paradox" observed in the binary model: among farmers with higher education, training was associated with more frequent, rather than less frequent, antimicrobial use. This interaction effect, viewed through an intersectionality lens, illustrates how the combination of educational capital and training creates a distinct social position characterised by greater confidence in autonomous medication practices (Crenshaw, 1989; Hankivsky, 2014).

Second, the interaction of farming experience with flock size significantly increased use frequency (OR = 1.20, 95% CI: 1.013–1.423, p = 0.035). This finding suggests that when experienced farmers manage larger flocks, they are more likely to use antimicrobials frequently, potentially reflecting the heightened economic stakes associated with larger investments. As a farmer with 8 years of experience and a flock of 800 birds explained:

> *"With more birds, the risk is bigger. If disease comes, I could lose everything I've built over years. So, I use medicine preventively, especially during risky seasons. Experience has taught me that prevention is cheaper than treatment when you have many birds."* (Male farmer, Kilimanjaro, 2024)

This quotation illustrates how production intensification pressures at the organisational level of the SEM may override the caution that might otherwise come with experience, leading to more frequent antimicrobial use as a risk management strategy (Lhermie *et al.,* 2019).

4.6.4 Non-significant predictors

Farming experience alone (OR = 0.715, p = 0.119) and education level alone (OR = 1.02, p = 0.909) were not significant predictors of usage frequency, reinforcing the importance of examining interaction effects rather than main effects in isolation. The non-significance of these individual factors, contrasted with the significance of their interactions, aligns with both the SEM's emphasis on multi-level influences and intersectionality's focus on combined social positions.

4.6.5 Threshold coefficients

All threshold coefficients except "Weekly | Daily" were statistically significant, indicating good discrimination between frequency categories. The non-significance of the "Weekly | Daily" threshold (p = 0.591) suggests that the distinction between weekly and daily use may be less pronounced than other category boundaries, potentially reflecting similar underlying drivers for these high-frequency usage patterns.

4.7 Structural constraints on antimicrobial stewardship

Findings from in-depth interviews and FGDs provided critical context for understanding the quantitative patterns, revealing structural constraints at multiple levels of the SEM that shape antimicrobial use practices and limit the effectiveness of individual-level interventions.

4.7.1 Limited training access at the organisational level

Despite the demonstrated protective effect of training in regression analyses, qualitative findings revealed that access to training is severely limited. A focus group participant in Buswelu, Mwanza, explained:

> *"The government sometimes brings training, but it is rare, maybe once every two or three years. And when it comes,*

Table 6: Ordinal logistic regression analysis of factors associated with antimicrobial use frequency (n = 246)

Variable	β	SE	Wald χ^2	OR	95% CI	p-value	VIF
Education level	0.020	0.171	0.01	1.02	0.73–1.43	0.909	1.24
Farming experience	−0.336	0.215	2.44	0.72	0.47–1.09	0.119	3.58
Training (received)	−1.907	0.845	5.09	**0.149**	**0.028–0.780**	**0.024**	8.46
Family size	−0.512	0.176	8.46	**0.599**	**0.424–0.847**	**0.0037**	1.20
Education × Training	0.789	0.395	3.99	**2.20**	**1.01–4.78**	**0.046**	8.62
Experience × Flock size	0.183	0.087	4.42	**1.20**	**1.01–1.42**	**0.035**	3.62

Threshold coefficients	β	SE	OR	95% CI	p-value
Never | Rarely	−3.037	0.611	0.048	0.014–0.159	**<0.001**
Rarely | Monthly	−1.768	0.591	0.171	0.053–0.545	**0.003**
Monthly | Weekly	−1.167	0.588	0.311	0.098–0.986	**0.047**
Weekly | Daily	−0.314	0.585	0.731	0.233–2.296	0.591

Note: OR = Odds Ratio; CI = Confidence Interval; VIF = Variance Inflation Factor. Model fit: Likelihood ratio χ^2 = 20.27, df = 6, p = 0.002. Statistically significant predictors (p < 0.05) are indicated in bold.

it is often for only a few farmers, and we are expected to share what we learned with others, but that doesn't work well. Most of us learn from each other or from the people selling medicine." (Female farmer, Mwanza, 2024)

This gap between the demonstrated effectiveness of training and its limited availability represents a critical failure at the organisational level of the SEM, constraining the potential for stewardship interventions to achieve population-level impact.

4.7.2 Veterinary access constraints at the organisational level

Limited access to veterinary services emerged as a pervasive theme driving inappropriate antimicrobial use. A farmer from Mvuleni, Mwanza, explained:

"Even with training, antibiotics are easier to get than vets. The vet is based in town, and if I call him, he might come after two or three days, or he might not come at all. But the agro-vet shop is just down the road, and they will sell me anything I ask for. So, if my chickens are sick, I go to the shop, not the vet." (Male farmer, Mwanza, 2024)

This quotation illustrates how constraints at the organisational level, specifically, the imbalance between accessible pharmaceutical supply chains and inaccessible veterinary diagnostic services, drive self-medication practices that increase antimicrobial use frequency and undermine prudent use, regardless of farmers'' knowledge or training.

4.7.3 Economic pressures at the individual and community levels

Economic pressures, particularly among farmers dependent solely on farm income, drove preventive antimicrobial use as a risk management strategy. A farmer from Boma Ng'ombe, Kilimanjaro, explained:

"I know I shouldn't use antibiotics without knowing the disease. But I cannot afford to wait and see. If I wait, I might lose half my flock. Then how will I pay school fees? How will we eat? So, I use medicine, even if I'm not sure what the disease is." (Female farmer, Kilimanjaro, 2024)

This narrative illustrates how economic precarity at the individual level, interacting with limited veterinary access at the organisational level, creates conditions where farmers perceive antimicrobial use as their only viable option for protecting livelihoods, a finding that aligns with research on the economic drivers of AMU in LMIC livestock systems (Lhermie *et al.,* 2019).

4.7.4 Gender dynamics at the interpersonal level

Gender dynamics shaped antimicrobial decision-making in ways that intersect with other social positions. A female farmer from Buswelu, Mwanza, explained:

"My husband buys the medicine because he has the money and the motorcycle to go to town. But I decide when it is needed because I am with the birds all day. Sometimes he doesn't want to buy because he thinks I am worrying too much, but I insist because I see the signs. It can cause arguments." (Female farmer, Mwanza, 2024)

This quotation illustrates how gender, intersecting with control over household resources and mobility, shapes antimicrobial decision-making processes at the interpersonal level. Women's proximity to daily flock management positions them to identify disease threats, but their access to antimicrobials may be mediated by men's control over financial resources and transportation, a dynamic that the intersectionality framework illuminates as the product of overlapping gender and economic positions (Crenshaw, 1989; International Centre for Antimicrobial Resistance Solutions, n.d.).

5.0 Conclusions and Recommendations

5.1 Conclusion

This study examined associations between socioeconomic factors and antimicrobial use (AMU) among broiler farmers in Kilimanjaro and Mwanza, Tanzania, using an integrated framework combining the Social Ecological Model and Intersectionality Theory. Findings reveal that AMU practices emerge from complex interactions across individual, interpersonal, organisational, community, and policy-level factors, with farmers' intersecting social positions; gender, education, income, family size, experience, and region; producing distinct usage patterns.

Significant regional disparities were documented: Mwanza farmers showed substantially higher AMU prevalence (91.1% vs 81.3%) and more intensive usage than Kilimanjaro farmers. These community-level differences likely reflect variations in production intensity, disease ecology, market integration, and veterinary infrastructure, underscoring the need for context-specific rather than uniform interventions.

Training was the strongest protective factor, reducing AMU odds by 95.6% and lowering usage frequency. However, qualitative findings revealed a critical implementation gap: training remains infrequent and reaches few farmers, representing a missed stewardship opportunity at scale. Family size also protected against frequent AMU, with each household size increase associated with 40.1% lower odds of frequent usage, likely reflecting labour advantages for disease prevention.

Theoretically, significant interaction effects validated intersectionality's central premise. The "competency paradox" where training combined with higher education increased rather than decreased AMU, suggests educated farmers may develop overconfidence in autonomous medication practices when veterinary access is limited. Similarly, experienced farmers with larger flocks used antimicrobials more frequently, indicating production pressures may override experiential caution.

Gender profoundly shaped practices: women, comprising most farmers, served as frontline decision-makers due to daily flock proximity, while men-controlled procurement, a dynamic stewardship programmes must address. Structural constraints, limited veterinary access and economic precarity, emerged as fundamental barriers that individual-level interventions alone cannot overcome.

In deduction, AMU among Tanzanian broiler farmers cannot be reduced to individual knowledge deficits. It emerges from intersecting socioeconomic positions, household structures, gender relations, institutional constraints, and regional contexts. Effective stewardship requires structurally responsive, context-specific interventions attentive to the intersecting social positions that shape farmers' relationships with antimicrobials.

5.2 Recommendations

Based on study findings, the following recommendations are proposed for promoting responsible antimicrobial use in Tanzanian broiler systems.

National and regional authorities should prioritise scaling up farmer training on antimicrobial stewardship, ensuring programmes are ongoing, practical, and delivered through accessible channels including community-based animal health workers, cooperatives, and digital platforms. Training must reach female farmers, who constitute the majority of poultry producers and frontline decision-makers.

Crucially, training approaches must be differentiated based on educational backgrounds to address the “competency paradox.” For educated farmers, training should emphasise the limitations of self-medication and importance of veterinary diagnosis rather than simply providing technical information that may foster overconfidence in autonomous practices.

Government must urgently improve access to veterinary diagnostic services, particularly in rural areas, through community-based animal health workers, tele-veterinary platforms, and subsidised visits. Simultaneously, regulatory frameworks governing antimicrobial sales should be strengthened to limit over-the-counter access without prescription, creating complementary pressure for veterinary consultation.

Gender-responsive interventions are essential: programmes should reach women directly, employ female extension officers, schedule training accommodating domestic responsibilities, and engage both men and women in discussions about antimicrobial decision-making and financing.

Interventions should support household-level disease prevention capacity through improved housing, hygiene, and biosecurity measures, with labour-saving technologies for smaller households. Context-specific approaches are needed: Mwanza requires addressing structural drivers of intensive use, while Kilimanjaro offers lessons in antimicrobial-free production that can be amplified.

Regulatory oversight must be strengthened through prescription enforcement, licensing agro-veterinary outlets, and establishing antimicrobial distribution tracking systems, accompanied by farmer awareness campaigns. Economic diversification programmes, off-farm income generation, savings schemes, agricultural insurance, can buffer households against production risks that drive antimicrobial dependence.

Strong monitoring systems should track both aggregate changes and differential effects across farmer subgroups to identify unintended consequences like the competency paradox. Finally, national antimicrobial resistance policies must integrate intersectionality and social ecology perspectives, recognising that antimicrobial use is shaped by interacting factors across multiple levels. Policies should enable context-specific adaptation while addressing structural constraints, limited veterinary access, economic precarity, gender inequalities, that individual-level interventions alone cannot resolve.

Acknowledgements

The authors extend their sincere gratitude to Olivier Rubin of the Department of Social Sciences and Business, Roskilde University, Denmark, and Madelaine Norström of the Departments of Animal Health, Animal Welfare and Food Safety, Norwegian Veterinary Institute, Norway, for their invaluable guidance, critical insights, and unwavering support throughout the research process. Their expertise and mentorship significantly shaped the conceptualization and execution of this study.

This work was funded by the INIKA_OH_TZ project (Interventions for Improved Knowledge and Awareness of Antimicrobial Resistance Using a One Health Approach in Tanzania), led by the Norwegian Veterinary Institute in partnership with Sokoine University of Agriculture. We are grateful for the financial support that made this research possible. The INIKA_OH_TZ project is funded by the Research Council of Norway’s Global Health Initiative (GLOBVAC3), project number 336223.

Declaration of Conflict of Interest

We hereby declare that there are no known competing financial interests or personal relationships that could have influenced the research and findings presented in this paper.

References

Alhaji, N. B., & Isola, T. O. (2018). Antimicrobial usage by pastoralists in food animals: A survey of knowledge, attitudes and practices in north-central Nigeria. *Veterinary World*, 11(2), 267-273. https://doi.org/10.14202/vetworld.2018.267-273

Atkinson, R., & Flint, J. (2001). Accessing hidden and hard-to-reach populations: Snowball research strategies. *Social Research Update*, 33(1), 1-4.

Azabo, R., Mshana, S., Matee, M., & Kimera, S. I. (2022). Antimicrobial usage in cattle and poultry production in Dar es Salaam, Tanzania: pattern and quantity. *BMC Veterinary Research*, 18(1), 1-12. https://doi.org/10.1186/s12917-021-03056-9

Brandström, P. (1990). *Boundless universe: The culture of expansion among the Sukuma-Nyamwezi of Tanzania*. Uppsala University.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.

Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press.

Caudell, M. A., Dorado-Garcia, A., Eckford, S., Creese, C., Byarugaba, D. K., Afakye, K., … & Grace, D. (2020). Towards a bottom-up understanding of antimicrobial use and resistance on the farm: A knowledge, attitudes, and practices survey across livestock systems in five African countries. *PLOS ONE*, 15(1), e0220274. https://doi.org/10.1371/journal.pone.0220274

Caudell, M. A., Quinlan, M. B., Subbiah, M., Call, D. R., Roulette, C. J., Roulette, J. W., … & Quinlan, R. J. (2017). Antimicrobial use and veterinary care among agro-pastoralists in Northern Tanzania. *PLOS ONE*, 12(1), e0170328. https://doi.org/10.1371/journal.pone.0170328

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *University of Chicago Legal Forum*, 1989(1), 139-167.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

de Leeuw, E. D. (2005). To mix or not to mix data collection modes in surveys. *Journal of Official Statistics*, 21(2), 233-255.

Dumas, S. E., Maranga, A., Mbullo, P., Collins, S., Wekesa, P., Onono, M., & Young, S. L. (2018). "Men are in front at eating time, but not when it comes to rearing the chicken": Unpacking the gendered benefits and costs of livestock ownership in Kenya. *Food and Nutrition Bulletin*, 39(1), 3-19. https://doi.org/10.1177/0379572117737428

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs—principles and practices. *Health Services Research*, 48(6pt2), 2134-2156. https://doi.org/10.1111/1475-6773.12117

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, 13(1), 117. https://doi.org/10.1186/1471-2288-13-117

Goutard, F. L., Bordier, M., Calba, C., Erlacher-Vindel, E., Góchez, D., De Balogh, K., … & Vong, S. (2017). Antimicrobial policy interventions in food animal production in South East Asia. *BMJ*, 358, j3544. https://doi.org/10.1136/bmj.j3544

Halsey, G. (2025, October 13). WHO: 1 in 6 common infections now drug-resistant, AMR threatens global health. *Patient Care Online*. https://www.patientcareonline.com/view/who-1-in-6-common-infections-now-drug-resistant-amr-threatens-global-health

Hankivsky, O. (2014). Intersectionality 101. Institute for Intersectionality Research & Policy, Simon Fraser University.

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., & Borriello, G. (2010). Open data kit: Tools to build information services for developing regions. In Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development (pp. 1-12). https://doi.org/10.1145/2369220.2369236

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression* (3rd ed.). John Wiley & Sons.

International Centre for Antimicrobial Resistance Solutions. (2023). *Mitigating the spread of antimicrobials and resistant microbes through treatment of manure* [Poster presentation]. ReAct Africa and South Centre Conference.

International Centre for Antimicrobial Resistance Solutions. (n.d.). *How gender and social inequities shape climate-AMR vulnerabilities: A rapid realist synthesis and conceptual framework development for livestock and aquaculture systems*. https://icars-global.org/projects/climate-amr-equity-framework/

Jacobsen, A. B. J. E., Ogden, J., Wakawa, A., Ekiri, A. B., & Nandi, S. (2025). A thematic analysis of motivators and barriers to antimicrobial resistance interventions with farmers and animal health professionals in Nigeria. *Veterinary Medicine International*, 2025, 8043291. https://doi.org/10.1155/vmi/8043291

Kabululu, M. L., Ngowi, H. A., Mlangwa, J. E. D., Mkupasi, E. M., Braae, U. C., Trevisan, C., … & Johansen, M. V. (2020). Tsutsa agrovet: A mobile-phone based intervention for improving poultry farmers' access to veterinary services in Tanzania. *BMC Veterinary Research*, 16(1), 1-12. https://doi.org/10.1186/s12917-020-02543-9

Kitzinger, J. (1995). Qualitative research: Introducing focus groups. *British Medical Journal*, 311(7000), 299-302. https://doi.org/10.1136/bmj.311.7000.299

Kutner, M. H., Nachtsheim, C. J., & Neter, J. (2004). *Applied linear regression models* (4th ed.). McGraw-Hill Irwin.

Lhermie, G., Wernli, D., Jørgensen, P. S., Kenkel, D., & Tauer, L. W. (2019). Tradeoffs between resistance to antimicrobials in public health and their use in agriculture: Moving towards sustainability assessment. *Ecological Economics*, 166, 106427. https://doi.org/10.1016/j.ecolecon.2019.106427

McCullagh, P. (1980). Regression models for ordinal data. *Journal of the Royal Statistical Society: Series B (Methodological)*, 42(2), 109-127. https://doi.org/10.1111/j.2517-6161.1980.tb01109.x

McKernan, C. (2021). *Socioeconomic determinants of agricultural practices in Lake Victoria basin*. East African Journal of Rural Development, 15(2), 78-94.

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly*, 15(4), 351-377. https://doi.org/10.1177/109019818801500401

Mdegela, R. H., Mwakapeje, E. R., Rubegwa, B., Gebeyehu, D. T., Nonga, H. E., & Mmbando, P. (2019). Antimicrobial use and resistance in livestock farming in Tanzania: A review. *Tanzania Veterinary Journal*, 37(1), 1-15.

Mdegela, R. H., Mwakapeje, E. R., Rubegwa, B., Gebeyehu, D. T., Nonga, H. E., & Mmbando, P. (2021). Antimicrobial use, residues, resistance and governance in the food and agriculture sectors, Tanzania. *Antibiotics*, 10(4), 454. https://doi.org/10.3390/antibiotics10040454

Mdemu, S., Matondo, A. B., Christensen, J. P., Amasha, A. E., Ngowi, H. A., Westwood, E., … & Mdegela, R. H. (2025). Factors influencing the frequency, knowledge, attitudes and practices of antibiotic use in commercial layer chicken farms, Tanzania. *Frontiers in Antibiotics*, 4, 1571096. https://doi.org/10.3389/frabi.2025.1571096

Mugisha, L., van der Meer, F., & Nankya, R. (2020). Gender dynamics in poultry management and its implications for antimicrobial use in Uganda. *Journal of Gender, Agriculture and Food Security*, 5(2), 1-15.

Mugisha, L., van der Meer, F., & Nankya, R. (2020). Gender dynamics in poultry management and its implications for antimicrobial use in Uganda. *Journal of Gender, Agriculture and Food Security*, 5(2), 1-15.

Mukhopadhyay, S., Peng, Y., & Tun, H. M. (2025). The 2024 WHO bacterial priority pathogens list: a critical evolution from a global One Health perspective. *Science in One Health*, 5, 100145. https://doi.org/10.1016/j.soh.2025.100145

Mushi, M. F., Mmbaga, E. J., Mshamu, S., Mdegela, R. H., & Mkupasi, E. M. (2019). Antimicrobial resistance in Salmonella spp. recovered from chicken carcasses and giblets in Tanzania. *Veterinary Medicine International*, 2019, Article ID 8569821. https://doi.org/10.1155/2019/8569821

Pramanik, P. (2025, October 14). Rising antibiotic resistance is putting routine infections back in the danger zone. *News-Medical*. https://www.news-medical.net/news/20251014/Rising-antibiotic-resistance-is-putting-routine-infections-back-in-the-danger-zone.aspx

Presser, S., Couper, M. P., Lessler, J. T., Martin, E., Martin, J., Rothgeb, J. M., & Singer, E. (2004). Methods for testing and evaluating survey questions. *Public Opinion Quarterly*, 68(1), 109-130. https://doi.org/10.1093/poq/nfh008

Rabbi, S. E., & Dey, N. C. (2019). Exploring the socioeconomic factors influencing small-scale poultry farming in Bangladesh. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 120(1), 67-78.

Ritchie, J., & Spencer, L. (1994). Qualitative data analysis for applied policy research. In A. Bryman & R. G. Burgess (Eds.), *Analyzing qualitative data* (pp. 173-194). Routledge.

STAR-IDAZ International Research Consortium. (2025). *Interventions for improved knowledge and awareness of antimicrobial resistance using a One Health approach in Tanzania (INIKA_OH_TZ)*. https://www.star-idaz.net/project/interventions-for-improved-knowledge-and-awareness-of-antimicrobial-resistance-using-a-one-health-approach-in-tanzania/

Tashakkori, A., & Teddlie, C. (2010). *SAGE handbook of mixed methods in social & behavioral research* (2nd ed.). SAGE Publications.

Thompson, S. K. (2012). *Sampling* (3rd ed.). John Wiley & Sons.

Tindana, P. O., Singh, J. A., Tracy, C. S., Upshur, R. E., Daar, A. S., Singer, P. A., … & Lavery, J. V. (2007). Grand challenges in global health:

Community engagement in research in developing countries. *PLOS Medicine*, 4(9), e273. https://doi.org/10.1371/journal.pmed.0040273

United Republic of Tanzania. (2021). National Agriculture Sample Census 2019/2020: Livestock sector report. Ministry of Agriculture, Livestock and Fisheries.

World Health Organization. (2025). *Global antibiotic resistance surveillance report 2025: WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS)*. https://www.who.int/publications/i/item/9789240116337

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, 310(20), 2191-2194. https://doi.org/10.1001/jama.2013.281053