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When the Cure is Worse than the Disease

Acaricide Use, Tick Resistance, and Systemic Constraints in Uganda's Dairy Sector

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Abstract

The Ugandan dairy sector has expanded rapidly in recent years. However, ticks and tick-borne diseases pose increasing challenges to this progress, exacerbated by the rise in resistance to acaricides, the primary method for tick control. This paper examines the systemic constraints that undermine effective, safe, and sustainable tick control in Uganda's liberalized dairy system. Drawing on multiple complementary data sources—including household surveys, exit interviews, list experiments, and covert audit methods—we show that the de facto farmer-led model of tick control is characterized by failures in information, coordination challenges, imperfect input markets, and weak regulation. Farmers operate with limited technical knowledge and minimal advisory support, and under extensive grazing systems and frequent inter-herd contact that require coordinated approaches to tick control. Input markets provide access to acaricides, but little guidance on proper use. As a result, misuse and overuse of chemicals are widespread, generating risks for animal and human well-being, food safety, and environmental integrity. Addressing these constraints will require integrated interventions that strengthen extension and regulatory capacity, improve accountability in veterinary input markets, and foster community-level coordination to ensure safe and sustainable tick control.

Keywords: Dairy value chains, ticks and tick-borne diseases, animal health, acaricide resistance, veterinary input markets, farmer behavior, coordination failures, information failures, value chain development

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1 Introduction

Uganda's dairy sector has become one of the country's most important agricultural sectors, contributing significantly to rural and urban livelihoods, national exports, and household nutrition. The sector has expanded rapidly: national milk production grew from 1.9 to 2.8 billion litres between 2014 and 2021, an increase of about 47 percent, and dairy export earnings reached USD 205 million in 2020, making dairy one of Uganda's top non-traditional exports. Per capita milk consumption has increased steadily over the past two decades, driven largely by rising urban demand (Van Campenhout, Minten and Swinnen, 2021). Dairy production has expanded rapidly, supported by growing domestic and export markets and investments in processing and value chain infrastructure (Nkuingoua Nana et al., 2022; Van Campenhout, Minten and Swinnen, 2021). In particular, foreign direct investment in the southwestern milk shed has catalyzed technological and institutional innovations, including the establishment of milk collection centers, the adoption of improved breeds and the expansion of processing capacity. The sector supports a wide range of actors—including smallholder farmers, herders, transporters, traders, input and animal feed suppliers, veterinary service providers (including artificial insemination), processors, and retailers—making it central to employment and enterprise opportunities in both rural and urban economies. The sector also contributes to foreign exchange earnings, as Ugandan dairy products are increasingly traded in the regional markets (Nkuingoua Nana et al., 2022).

Despite this growth and modernization, the persistence and intensification of ticks and tick-borne diseases now pose a critical challenge to sustaining productivity and competitiveness in Uganda's dairy sector. Ticks and tick-borne diseases impose substantial economic losses through animal mortality, reduced milk and meat productivity, high prevention and treatment costs, and foreign exchange outflows for imported tick control chemicals (acaricides) (Yadav and Upadhyay, 2024; Oscar Jaime Betancur and Cristian, 2018; Yadav and Upadhyay, 2024; Ocaido, Muwazi and Opuda, 2009). The development of tick resistance to acaricides is a particularly critical challenge, as it further complicates disease management and increases control costs. While the economic impact of ticks and tick-borne diseases on Uganda's livestock sector has not been well established, a presidential technical advisory team on ticks and tick-borne diseases estimated the economic loss at 3.8 trillion Uganda shillings annually (approximately 1 billion USD) (Presidential Scientific Research and Innovations Team , PSORT). Much of these losses are attributed to calf mortality, loss of milk and meat productivity, cost incurred on prevention and treatment of tick-borne diseases, and forex outflow through importation of acaricides and tick-borne disease drugs worth 300 billion Uganda shillings annually.

Chemical control using acaricides is the most widely employed method for managing ticks because of its rapid effectiveness. However, prolonged and improper use of acaricides can lead to resistance development, reducing their effectiveness over time (Vudriko et al., 2016). This makes it essential to implement management practices that delay resistance and preserve the long-term efficacy of available products (Abbas et al., 2014). Sustainable use of acaricides is technically demanding: users must understand tick biology, the differences between acaricide classes, and the importance of rotating between classes with distinct modes of action. They must also adhere to correct dosages, seasonal spraying schedules, and application methods that ensure full-body coverage. Any lapse in this process accelerates the development of resistance. The widespread emergence of multiple acaricide-resistant tick populations—especially in Southwestern Uganda—highlights the growing challenges facing the current approach to tick control (Vudriko et al., 2016; Byaruhanga et al., 2020).

Before the liberalization and structural adjustment programs of the 1990s, the Ugandan government-led dip system managed this technical complexity centrally, with dipping as the main method of acaricide application[1] and dip managers coordinating the use and rotation of acaricides. Zoning was implemented to ensure coordinated use of acaricides within the same geographic areas: farmers in a given zone used the same class of acaricide at any given time, to

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[1] Dipping ensures full-body coverage with the acaricide, including hard-to-reach areas such as the underbelly and inner thighs, thereby minimizing suboptimal exposure and reducing the likelihood of resistance development.

maintain uniform rotation and reduce the risk of resistance.[2] Liberalization dismantled this model, shifting responsibility for tick control to individual farmers, supported in principle by extension services and public veterinary officers. The government's role was reduced primarily to market regulation, while the private sector became responsible for supplying acaricides.

This shift from a government-led to a *de facto* farmer-led model raises a critical policy question: Can smallholder farmers, operating within liberalized input markets and facing major institutional constraints—including limited extension capacity and weak regulatory oversight—effectively manage a task as complex and collective as chemical control of ticks? This question is especially pressing given the rapid increase in acaricide resistance documented in Uganda.

To address this question, we conceptualize tick control and acaricide resistance as outcomes of broader systemic dynamics rather than isolated farmer-level decisions. We develop a conceptual framework that integrates four interlinked domains—technical complexity and information failures, coordination failures, input market imperfections, and externalities—to illustrate how these factors interact to undermine sustainable tick control in smallholder dairy systems. Using multiple complementary data sources—including household surveys, exit interviews, list experiments, and covert audit methods—we document prevailing practices, identify gaps in knowledge and information flows, and assess the potential coordination failures inherent in current livestock production systems. We also examine how input market imperfections and weak regulatory conditions contribute to the growing resistance crisis. In doing so, we position tick control as a binding constraint not only for animal health, but also for dairy value chain upgrading, food safety, and broader rural development.

The remainder of the paper is organized as follows. Section 2 provides background on

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[2] Zoning is important because it coordinates acaricide use across neighboring farms. When farmers in the same area use the same acaricide class repeatedly, ticks are continually exposed to chemicals with the same mode of action, accelerating resistance. Conversely, if adjacent farms use different classes, it can disrupt coordinated rotation schemes. The problem is compounded in areas where herds mix at common grazing and watering points, allowing resistant ticks to spread easily between farms

ticks and tick-borne diseases and the evolution of tick control in Uganda. Section 3 presents the conceptual framework. Section 4 describes the study design and data sources. Section 5 presents results guided by the framework, and Section 6 concludes with implications for policy and future research.

2 Study context

This section examines the biological, chemical, and institutional foundations of tick control in Uganda to explain the origins of the current resistance crisis. It begins by describing the major tick species and tick-borne diseases affecting livestock in Uganda. The section then highlights the widespread reliance on chemical control and examines the mechanisms and patterns of emerging acaricide resistance. Finally, it traces the evolution of Uganda's tick control system—from the centrally coordinated dipping programs of the mid-20th century to the present farmer-led and market-driven approach. Together, these elements provide the foundation for understanding how systemic changes in technology, institutions, and governance have shaped the current dynamics of resistance discussed in later sections.

2.1 Ticks and tick-borne diseases in Uganda

Uganda hosts a range of hard tick species, primarily classified under the genera Rhipicephalus, Amblyomma, and Hyalomma, with more than 15 species reported (Balinandi et al., 2020). The most economically significant are Rhipicephalus appendiculatus (brown ear tick) and Rhipicephalus (Boophilus) spp. (blue cattle tick), which together account for more than 90% of cattle losses caused by ticks and tick-borne diseases. These species are most prevalent in the southwestern regions of Uganda.

The importance of ticks arises largely from the pathogens they transmit to both livestock and humans. In Uganda, the most economically significant tick-borne pathogens belong to four genera: Theileria, Babesia, Anaplasma, and Cowdria spp. Among these pathogens, Theileria parva — the causative agent of East Coast Fever — is the most prevalent and lethal, with reported infection rates ranging from 47.4% to 64.1%, making it the leading cause of mortality in exotic cattle and their crosses, and responsible for up to 30% calf mortality in Uganda (Kasozi et al., 2014; Tayebwa et al., 2018; Ocaido, Muwazi and Opuda, 2009). Infected cattle that recover often remain carriers, posing persistent challenges for disease control. Other important, though less prevalent, tick borne diseases in Uganda include anaplasmosis, babesiosis, and heartwater disease.

2.2 Chemical control and the emergence of resistance

Chemical control using acaricides remains the most widely adopted method for managing tick infestations because of its rapid action and cost-effectiveness in suppressing tick populations. Acaricides are classified into different groups based on their active ingredients and modes of action. As of August 2022, the Ugandan National Drug Authority Veterinary Drug Register lists 66 generic products approved for tick control in livestock in Uganda. These can be divided into conventional and non-conventional classes. Conventional acaricides—specifically formulated for external tick control—include synthetic pyrethroids (13 products), amidines (10 products), co-formulations of organophosphates and synthetic pyrethroids (2 products), and organophosphates (1 product). The non-conventional class consists primarily of ivermectins (42 products), which are endectocides designed for both internal and external parasites but are increasingly used for tick management due to their systemic mode of action and reported efficacy against resistant tick strains. All acaricide products registered for use in Uganda are imported, predominantly from China—which accounts for nearly half of all registered formulations—followed by Jordan, India, Belgium, South Africa and the United Kingdom.

Despite their convenience and rapid efficacy, reliance on chemical control carries a major risk—the development of tick resistance to acaricides. Resistance is defined as ”the ability of a parasite strain to survive and/or multiply despite the administration and absorption of a drug given in doses equal to or higher than those usually recommended, but within the limits of tolerance of the host” (Abbas et al., 2014).

There are three main forms of resistance of ticks to chemicals. Acquired resistance develops gradually through genetic selection when ticks survive repeated exposure to a specific acaricide product. Cross-resistance occurs when resistance to one acaricide product confers tolerance to another product with a similar mode of action, limiting the effectiveness of switching products within the same chemical class. Multiple resistance arises when ticks become resistant to two or more unrelated acaricide classes, often due to prolonged misuse or inadequate rotation. Multiple resistance represents the most severe challenge because it drastically reduces the range of effective chemical options available for control.

Resistance develops through a combination of genetic, operational, and biological factors. Genetically, it emerges when heritable mutations that confer reduced susceptibility are selected over time. Operational factors play a major role in accelerating this process. Extended and frequent use of the same product or chemical class, under-dosing, and improper application increase selection pressure, allowing resistant tick populations to survive and proliferate. Resistance is also more likely to occur when ticks are repeatedly exposed to sub-therapeutic concentrations of acaricides—resulting from inadequate mixing, poor-quality products, or irregular treatment schedules. High treatment frequency, particularly when using the same acaricide over extended periods, further predisposes tick populations to resistance.

Given the high cost and effort of developing and registering new acaricides (Sparks, 2025), effective stewardship of existing compounds is critical. Key measures include ensuring that quality drugs are used, applying correct dosages, following recommended spraying intervals and techniques, and rotating products across different chemical classes to minimize selection pressure (Abbas et al., 2014).[3]

Resistance to acaricides has been documented in Uganda. The first cases were reported in the 1970s, when resistance to organochlorines was identified (Kitaka, Oteng and Kamya, 1970). Subsequent warnings in the 1990s about poor acaricide use practices—such as incorrect dilution, irregular rotation, and inadequate spraying—went largely unaddressed, setting the stage for the current crisis. Between 2013 and 2014, Vudriko et al. (2016) confirmed widespread multiple acaricide resistance in R. appendiculatus and R. (Boophilus)

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[3] To prevent cross- or multiple resistance, rotation should be based on the active ingredient's mode of action rather than switching between products with different trade names but within the same class.

decoloratus across Southwestern and Central Uganda, with particularly high resistance to synthetic pyrethroids and their co-formulations with organophosphates. Follow-up studies revealed rapid worsening of resistance: by 2014, 85% of ticks in Mbarara district, South Western milk shed, were resistant to amidines, and by 2019, 92% of tick samples from the same area showed resistance to multiple acaricide classes (Byaruhanga et al., 2020).

2.3 Evolution of tick control in Uganda

Tick control in Uganda began in the 1930s with the introduction of synthetic chemicals. However, a more organized approach emerged in the 1960s with the introduction of exotic cattle, which were highly susceptible to tick infestations. The government at the time rolled out a national tick eradication policy that recognized the role of indigenous cattle as reservoirs of ticks and tick-borne diseases and therefore emphasized mass chemical control. Communal dips were established across the country, and "dip scouts" were recruited to work alongside area veterinarians to oversee proper dip management and acaricide use.

In the 1970s, the government introduced a zoning system to coordinate acaricide rotation at scale. Acaricides were centrally procured by the ministry responsible for livestock and distributed through district veterinary departments, ensuring that farmers within a given zone used the same chemical class during a particular rotation period. This centralized system was effective for a time—it standardized tick control, ensured professional oversight, and delayed the emergence of resistance through coordinated acaricide management.

The situation changed dramatically with the introduction of the World Bank and IMF–supported structural adjustment programs in 1987. These reforms sought to reduce public expenditure and promote private sector participation in service delivery. In the process, the Ministry of Animal Industry and Fisheries was merged with the Ministry of Agriculture to form the Ministry of Agriculture, Animal Industry and Fisheries, while most operational responsibilities—including tick control, vaccination, and extension—were devolved to district local governments. Budgetary allocations to livestock services declined sharply, and many animal health staff were retrenched. As a result, the previously organized, government-led tick control program collapsed. Dip maintenance declined, acaricide procurement ceased, and the government's role shifted from implementation to regulation.

By the early 1990s, the liberalization of the veterinary input market had ushered in a new model of tick control—one led largely by farmers and supplied through private veterinary drug outlets. The National Drug Authority, established in 1993, was mandated to regulate veterinary medicines, but the actual distribution and sale of acaricides became fully privatized. Drug outlets emerged as the main access points for acaricides, often becoming the de facto advisory centers for farmers. The collapse of centralized dipping infrastructure, combined with under-resourced local veterinary services, left farmers to manage a technically demanding task with little professional or institutional support.

3 Conceptual Framework

The widespread emergence of tick resistance to acaricides in Uganda underscores the need to revisit the dominant farmer-led model of tick control. This model, adopted in the wake of liberalization and the dismantling of government dip stations, rests on the assumption that with access to veterinary drugs and support from public extension services, farmers can successfully manage the risk of tick-borne diseases.

We argue that this assumption is increasingly untenable. Effective tick control requires meeting demanding technical requirements at the farm level, yet these are difficult for smallholders to follow consistently. Weaknesses in public extension and private information channels further constrain farmer knowledge and practice. In addition, uncoordinated actions across geographic areas and grazing units undermine even well-intentioned efforts, while the social, environmental, and food safety externalities of misuse are rarely internalized. Together, these challenges reduce the effectiveness of the farmer-led model and generate unintended consequences.

To motivate our empirical analysis, we present a conceptual framework that integrates these interlinked constraints—technical requirements, information and extension limitations, coordination challenges, "lemon technologies" (Bold et al., 2017), and externalities—and underscores the limits of relying solely on individual or market-driven actions to achieve sustainable tick control. Figure 1 summarizes this conceptual framework, highlighting how sustainable tick control depends on meeting technical requirements at the farm level, coordinated action at the community level, and safeguards at the system-level against adverse selection and externalities.

3.1 Technical complexity and information constraints

The effective use of acaricides requires more than simple access to drugs. Farmers must understand tick biology, the differences between acaricide classes, and the importance of rotating between classes with distinct modes of action. They also need to follow seasonally appropriate spraying schedules, mix chemicals at the correct dilution, and apply them with equipment that ensures full-body coverage. Any mistake along this chain, whether in class rotation, dosage, frequency, or application method, can accelerate the development of resistance. These requirements are cumulative, interdependent, and difficult for smallholders to consistently execute, particularly given their limited training and access to professional veterinary support.

In principle, public extension services are mandated to provide this technical guidance. In practice, however, their effectiveness depends heavily on institutional capacity. In much of sub-Saharan Africa, extension systems operate with limited resources, low staff motivation, and inadequate facilitation (Norton and Alwang, 2020; Bashaasha, Najjingo Mangheni and Nkonya, 2013). Private input suppliers often serve as the primary point of contact for farmers, but they may face incentive misalignments, information gaps and inequitable provision of services (Kariuki et al., 2025; Dar et al., 2024; Feder, Birner and Anderson, 2011), which may limit their effectiveness as reliable advisors.

Even when information is technically available, for example, through drug labels or National Drug Authority brochures, this information can be ignored or misunderstood due to low literacy, limited attention, or other behavioral biases (Rutsaert et al., 2024). Sustainable tick control, therefore, requires more than passive information provision, but consistent, credible, and repeated interactions that help farmers translate complex technical guidance into practice.

3.2 Coordination challenges

Resistance to acaricides is inherently a spatial problem. Even when individual farmers adopt recommended rotation strategies, their effectiveness is undermined if neighboring farmers continue to use the same class of acaricide or apply them incorrectly, thereby accelerating the spread of resistant ticks. Coordination becomes especially critical under conditions where herds intermingle, such as open and communal grazing systems, shared watering points, or contiguous and semi-porous farm boundaries,[4] because ticks move easily between animals and households. In such contexts, even well-intentioned practices are quickly undone by neighbors' actions unless chemical use is synchronized. Without institutions or incentives for collective adherence, resistance management is difficult to sustain, and isolated good practices risk being overwhelmed by the weakest links in the community system.

The above touches on the common-pool resource literature (Osten, Kirley and Miller, 2017) and collective action theory introduced by Ostrom (1990) and subsequent work on externalities and coordination in pest and disease control (Hennessy and Wolf, 2018; Lence and Singerman, 2023; McKee, 2011). A tick-free environment (typically tick-free common grazing land) can be viewed as a shared good—non-excludable but rivalrous—since one farmer's failure to control ticks effectively diminishes the benefits for others. Individual incentives are misaligned: the private gains from proper tick management are reduced when others do not participate, while the costs of collective success are easily shifted through free riding. As a result, rational individual behavior leads to socially suboptimal outcomes, analogous to overuse or underinvestment in other shared resource systems.

Given these market failures, effective management requires mechanisms that align individual actions with collective outcomes. These may include social norms that encour-

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[4] Common examples in Southwestern Uganda would be adjacent fields separated by thin hedges/living fences, post-and-rail or split rail fences that impede animals crossing boundaries, but allow for physical contact between animals.

age synchronized spraying and shared learning, community-level institutions (e.g., grazing committees, cooperatives) that coordinate rotation schemes and enforce agreed practices, or regulatory frameworks that define and monitor standards of acaricide use. As each of these strategies have their own benefits and limitations, in many settings, combining formal rules with locally embedded norms—supported by trusted intermediaries and accessible information—offers the most promising path toward collective and durable tick resistance management.

3.3 Input market imperfections

Farmers obtain acaricides through liberalized input markets, but information asymmetries frequently give rise to adverse selection, where low-quality products drive out high-quality ones (Ashour et al., 2019; Michelson et al., 2021; Bold et al., 2017). Acaricides have credence characteristics: their quality and efficacy cannot be directly observed by farmers, either at the point of purchase or even immediately after use. As a result, farmers cannot easily determine whether poor control outcomes are due to resistant ticks, ineffective application methods, or substandard products.

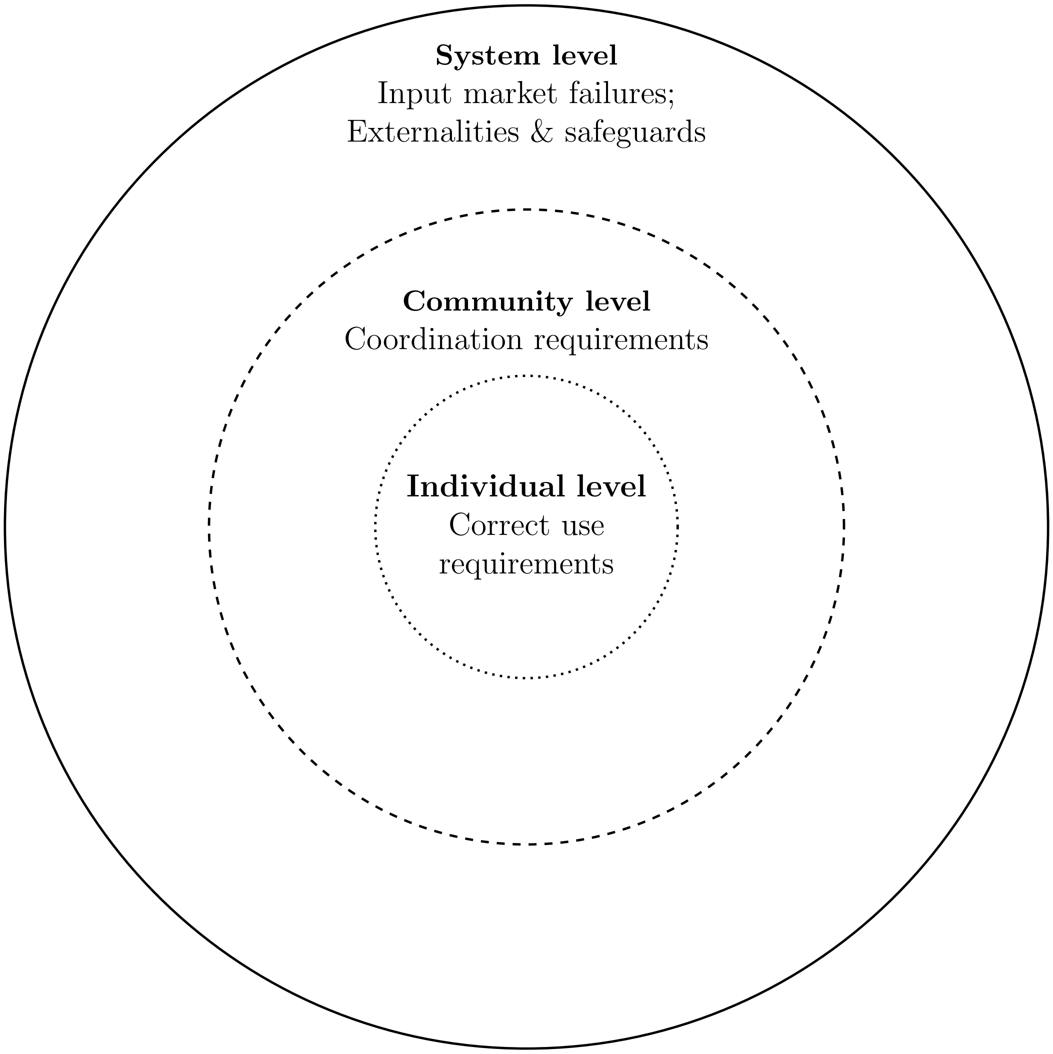
Because farmers cannot reliably assess quality, they are only willing to pay an average price that reflects the expected mix of good and bad products in the market. This price may be too low to make it profitable for reputable suppliers to stock and market high-quality acaricides. Over time, low-quality or counterfeit products drive out the good ones, as in Akerlof (1970) ”market for lemons.” The result is a market dominated by ineffective or substandard acaricides, which not only waste farmers’ money but also accelerate the emergence of acaricide resistance, since ticks are repeatedly exposed to ineffective acaricides.

Even when the inputs or information from dealers are of good quality, farmers may perceive them as ineffective or of poor quality (Michelson et al., 2021). In cases where tick resistance due to poor application practices is the true cause of poor drug performance, farmers may attribute the problem to counterfeit or low-quality drugs. These erroneous perceptions of product failure can erode trust in private input suppliers, encourage ”trial-and-error" purchases, and push farmers toward unapproved or unsafe chemicals. Together, these dynamics may further accelerate resistance and undermine safe tick control, highlighting another structural limitation of the farmer-led model.

3.4 Externalities

As resistance grows and acaricide efficacy declines, farmers may adopt coping strategies that generate costs beyond their own herds. These include practices such as mixing acaricides with crop pesticides, increasing application frequency, or resorting to unapproved chemicals. The consequences of such actions extend beyond the individual farm as they can leave harmful residues in milk and meat, pose health risks to humans and animals, and degrade soils and water systems. These externalities are particularly acute where output markets lack effective mechanisms to internalize costs or where enforcement of regulations is weak. In contexts like SSA, where safety standards in domestic milk markets are missing or weakly enforced (Jaffee et al., 2018), producers face little reputational or financial penalty for unsafe practices, reinforcing the use of illicit fixes.

This highlights a systemic weakness of the farmer-led model: without collective safeguards, the misuse of acaricides not only undermines animal health and productivity but also generates broader public health and environmental risks that individual farmers have little incentive or capacity to address.



Individual level

Correct use requirements

- Identify tick species and risks.
- Select the correct acaricide class (modes of action).
- Rotate across classes on a proper schedule.
- Mix the correct dosage/dilution (precision, equipment, literacy).
- Apply correctly (full-body wetting; proper pumps/sprayers).
- Follow seasonal spraying schedules (weekly wet; fortnightly dry).
- Complement with management (rotational grazing; avoid free-range).

Community level

Coordination requirements

- Synchronize spraying schedules within villages/grazing units.
- Harmonize rotation across classes to avoid local overuse.
- Manage communal grazing/watering to reduce reinfestation.

System level

Market/system failures

- Monitor acaricide quality and ensure proper handling by vendors
- Ensure farmer beliefs are alligned with quality of the products
- Enforce withdrawal periods; residue testing (milk/meat).
- Prevent unsafe coping (e.g., pesticide mixing).

Figure 1: Conceptual framework

4 Data sources

Our study focuses primarily on dairy farmers in the Southwestern and parts of the Central and Western milksheds (Figure 2). These regions constitute some of the most important production zones for Uganda's dairy sector, with the Southwestern milkshed being particularly significant and accounting for 32.5% of national milk output (Uganda Ministry of Finance, Planning and Economic Development, 2025). Within this region, our study focused on 11 districts that constitute the bulk of dairy production: Bushenyi, Ibanda, Isingiro, Kamwenge, Kazo, Kiruhura, Lyantonde, Mbarara, Ntungamo, Rwampara, and Sheema.

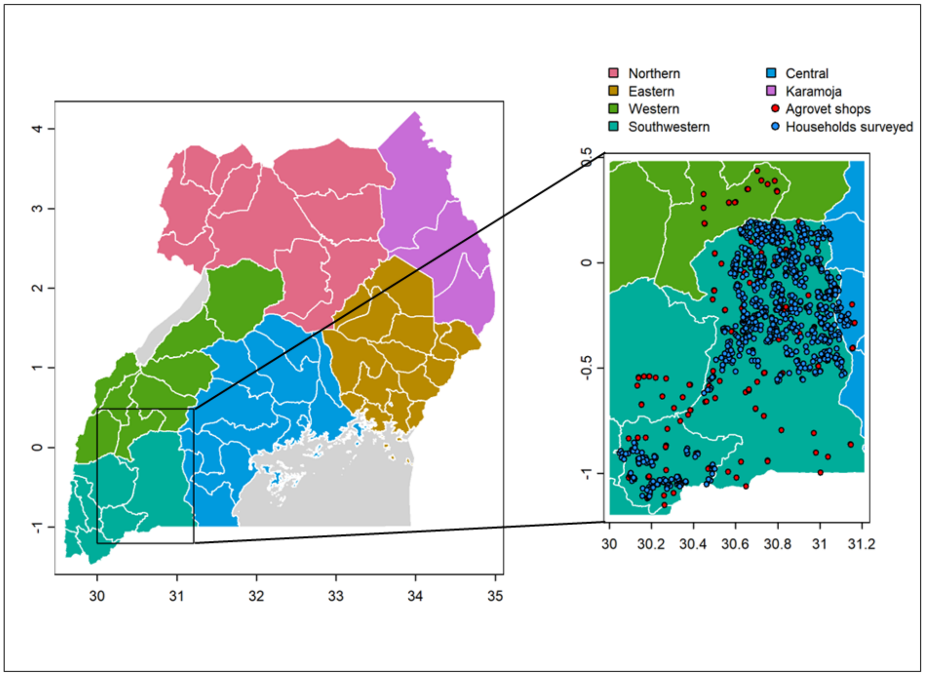


Figure 2: Map showing Uganda's milksheds and the spatial distribution of sampled dairy farmers and veterinary shops

We draw on various data sources. First, a household survey was conducted in 2022, covering 926 dairy farming households in four districts (Kazo, Kiruhura, Mbarara, and Ntungamo). To sample these farmers, we visited a random sample of 125 milk collection centers, and randomly selected 8 farmers from the farmers that delivered to these milk collection centers. The survey collected information on the prevalence and impacts of tick and tick-borne diseases, management practices, chemical use, and farmer knowledge of acaricide rotation and application. As we will explain in the results section, the survey also included a list experiment to elicit truthful responses on potentially sensitive practices, such as the misuse or mixing of acaricides, without directly asking respondents to disclose them.

Second, we conducted 411 farmer exit interviews in 2023 outside veterinary drug shops spread across the 11 districts. We aimed to interview at least two farmers per shop immediately after purchasing drugs. These interviews captured the type of acaricide purchased, knowledge of different acaricide classes, understanding of rotation strategies, and sources of advice. To probe farmers' engagement with existing information sources, we presented respondents with the National Drug Authority leaflet (Figure 6 in the Appendix), which lists acaricide classes and recommended rotation practices, and asked whether they had seen it before. We also asked about attention to drug labels and how such information influenced purchase decisions.

Combining household surveys with exit interviews allows us to triangulate reported practices with observed behavior at the point of purchase. Household surveys capture broader production practices, disease burdens, and long-term management strategies, but they may be affected by recall bias or social desirability. Exit interviews, conducted immediately after transactions in drug shops, provide more accurate information on actual purchasing decisions, the quality of advice received, and the role of labels and information materials. These exit interviews are however based on a narrower sample of farmers, specifically those who purchase, so the conclusions may not be generalized in the same way as those from the household survey. Together, these two sources offer a more comprehensive picture of how farmers make decisions about acaricide use, revealing both their stated practices and the constraints they face in real time.

In addition to exit interviews, we employed a covert audit approach, in which an enumerator (mystery shopper), posing as a regular customer, visited agro-vet shops to purchase acaricides. Mystery shopper enumerators were assigned to gather data on acaricide dispensing practices. In line with a mystery shopper research protocol, the enumerators were guided on how to mimic typical farmer behavior while purchasing acaricides from local veterinary drug shops and had to record the survey data after exiting the shop premises. Each shop was visited three times by a different shopper under a different scenario.

In *scenario-1 (S1)*, the mystery shopper requested to buy one liter of a popular acaricide brand, *Milibitraz*, and the mystery shopper/enumerator took note of whether and how the drug seller made an attempt to influence the choice of acaricide bought, considering the prior pre-specified farmer preference product. Additionally, the enumerator took note if the seller offered any guidance on proper acaricide use.

In *Scenario-2 (S2)*, the mystery shopper described a persistent issue of ticks becoming "stubborn" on the farm and mentioned the acaricide being used on the farm being ineffective, expressing interest in switching to a product that could be more effective. The enumerator noted any piece of advise provided and the new product, as recommended by the drug seller. In this scenario, we desired to know if the drug seller had knowledge and understanding of various acaricide classes and proper practice of acaricide rotation.

In *Scenario-3 (S3)*, the mystery shopper approached the veterinary drug seller and inquired about the possibility of using acaricide concoctions or the use of higher concentration above the manufacturer's recommendation, considering the acaricide currently in use by the farmer was no longer effective against ticks. The mystery shopper noted the advice provided by the shop seller and entered the data after exiting the shop.

5 Results

We begin by examining the burden of ticks and tick-borne diseases and the associated costs they impose on farmers. We then analyze farmer-reported management practices, highlighting key gaps in current control strategies. Next, we assess farmers' knowledge of correct acaricide rotation practices and describe prevailing grazing systems that reveal the potential for coordination failures in tick control. Finally, we document management practices that may generate externalities extending beyond the farm level. Results are organized around the four systemic domains identified in the conceptual framework—technical complexity, coordination challenges, input market imperfections, and externalities—to document how these interlinked failures undermine effective tick control.

5.1 The burden of ticks and tick borne diseases: prevalence and costs

Table 1 summarizes household survey data on the prevalence of ticks and tick-borne diseases. Almost all farmers (95%) identified ticks as a major problem in dairy production, and approximately three-quarters reported at least one tick-borne disease in the past year, with a median of six animals affected per household. East Coast Fever was the most frequently mentioned disease.

Mortality losses were widespread: about half of all farmers lost at least one animal to ticks and tick borne diseases, with an average of three deaths per household. Such losses are particularly consequential in smallholder systems, where cattle serve not only as a source of milk but also as a form of wealth, insurance, and collateral. Income from livestock commonly finances essential household needs such as food, education, and health care (Ransom, Bain and Halimatusa'diyah, 2017), meaning ticks and tick borne diseases shocks extend well beyond herd productivity to affect overall welfare.

Financial costs further compound these effects. The most direct expenses arise from acaricides and other disease management inputs. According to farmer-reported data, the median household spent approximately UGS 3,380,000 (approximately USD 890) in the preceding year on acaricides and tick borne diseases treatment, equivalent to total annual dairy revenue from ≈ 3.5 cows (Omondi et al., 2017).

Ticks and tick borne diseases affect productivity directly by reducing milk production and indirectly by influencing farmer breed choices. Under high disease pressure, some farmers may revert to more resilient indigenous cattle breeds. Although this reduces losses, it lowers milk yields and may discourage investment in complementary technologies, such as improved breeding or feeding practices. Overall, ticks and tick borne diseases impose a heavy burden on dairy farmers through high prevalence, livestock mortality, and substantial treatment costs.

Table 1: Prevalence of ticks and tick-borne diseases in the previous 12 months

	Mean	SD	Median	N
Farmer reported ticks was a problem	0.945	0.228	1	926
Farmer experienced a TBD last 12 months	0.756	0.430	1	926
Farmer experienced ECF disease	0.708	0.455	1	926
Farmer experienced anaplasmosis disease	0.225	0.418	0	926
Farmer experienced babesiosis disease	0.193	0.395	0	926
Farmer experienced heart water disease	0.116	0.320	0	926
Number of animals affected by a TBD	11.009	11.763	6	926
Farmer lost an animal to a TBD	0.517	0.500	1	926
Farmer lost 1-9 animals to a TBD	0.390	0.488	0	926
Farmer lost more than 9 animals to TBD	0.122	0.327	0	926
Number of animals that died from a TBD	2.545	3.434	1	923
Amount spent treating TBD during dry season	377290.2	501179.6	150000	920
Monthly expenses for acaricides	191074.4	145114.2	140000	921
Monthly expenses for acaricides (wet season)	207137.4	145599.8	150000	921
Monthly expenses for acaricides (dry season)	191945.1	137910.2	150000	920

Note: Data from the household surveys in 2022, covering the last 12 months of production. Data on disease prevalence were based on farmer self-reports. For each tick-borne disease, enumerators described the main clinical symptoms, and farmers indicated whether they had observed such symptoms in their herds during the previous year. Continuous variables winsorized at 0,90, leading to slight differences in sample size.

5.2 Tick management practices and acaricide rotation behavior

Table 2 summarizes the strategies that farmers reported using to manage ticks. Chemical control dominates: almost all farmers (99%) reported using acaricides as their primary control method. Vaccination against East Coast Fever was mentioned by nearly 40% of households. While vaccination does not directly reduce tick populations, it can mitigate disease severity and mortality, thereby lowering the demand for intensive acaricide application. Other practices such as hand-picking of ticks or maintaining local breeds were reported only marginally.

The frequency and methods of acaricide application show substantial divergence from recommended protocols. During the wet season, 83% of farmers sprayed their animals weekly and 16% did so twice in one week. Thus, almost all farmers applied acaricides at least once a week during the wet season, even though a once-every-three-weeks schedule is recommended during the tick season in areas where resistance is common (Sugimoto and Osakabe, 2014). High frequency of acaricide application not only raises production costs but also accelerates the development of resistance (Abbas et al., 2014; Thullner, Willadsen and Kemp, 2007; Jonsson, Mayer and Green, 2000) and poses potential environmental and public health risks.

The current acaricide application methods are also constrained. The vast majority of farmers (92%) rely on manual hand-spraying, while only 5% use powered sprayers, and none report access to dipping facilities. Hand-spraying is often ineffective because it fails to achieve full-body wetting, leading to uneven coverage and chemical wastage. Incomplete or uneven application can also accelerate resistance development, as ticks that receive only partial exposure are more likely to survive and pass on resistant traits. Equipment limitations exacerbate the problem: roughly one-third of farmers reported using improvised or inappropriate tools instead of the recommended bucket pump for hand-spraying.

Table 2: Tick management practices

	Proportion of farmers	N
Chemical control	0.989	926
Rotational grazing	0.052	926
Hand-picking of the ticks	0.017	926
Keeping traditional breeds	0.001	926
Vaccination aganist ECF	0.366	926
Frequency of spraying during dry season		
Once a week	0.825	916
Twice a week	0.163	916
Once in two weeks	0.003	916
Three times a week	0.002	916
Frequency of spraying during the wet season		
Once a week	0.870	916
Twice a week	0.124	916
Once in two weeks	0.002	916
Method of application		
Dipping	0.004	916
Scrubbing	0.005	916
Hand spraying	0.919	916
Powered spraying (eg spray race)	0.049	916
Equipment used during spraying		
Bucket pump/ foot pump	0.645	916
Dip	0.001	916
Hand sprayer	0.287	916
Knapsack sprayer	0.045	916
Scrubbing cloth	0.007	916
Spray race	0.013	916

Note: Data from the household surveys in 2022. Sample size varies due to non-response.

Next, we examine the types of chemicals and rotation procedures implemented by the farmers in our study. Farmers were asked during the household surveys to state the product they were currently using and the product they had used prior to the current one. These responses were then used to identify the corresponding acaricide classes. Approximately 80% of farmers reported using an acaricide from the amidine class at the time of the study, while about 17% were using a mixture of organophosphates and pyrethroids co-formulations. Fewer farmers reported using products from the pyrethroid or lactone classes. Comparable patterns were observed for previously used acaricides: roughly 70% had earlier used amidines, while about 30% had used co-formulations. A 2015 study revealed a similar pattern, with around 86% of farmers using either of these two classes (Vudriko et al., 2018).

A closer look at switching behaviour reveals limited rotation across classes. Figure 3 presents a Sankey diagram illustrating that farmers practice very little rotation between acaricide classes. The percentages shown represent the distribution of farmers within each current acaricide class, indicating the proportion of current users who had previously used the same class versus those who shifted from other classes.

For the most commonly used class—amidines—the majority of farmers had been using the same class previously, demonstrating strong within-class persistence among farmers in our sample. Specifically, among farmers currently using amidines, roughly two-thirds had also used amidines before, while most of the remaining users had shifted from organophosphate–pyrethroid mixtures, with only a very small share coming from pyrethroids or macrocyclic lactones. A similar pattern is observed for farmers currently using macrocyclic lactones.

By contrast, the pattern differs for pyrethroids and organophosphates co-formulations + pyrethroids. Among current users of these classes, only about one-third had previously used the same class, whereas the majority had switched from amidines. However, these users represent a minority of farmers in the sample.

Thus, rotation between classes remains relatively limited overall, suggesting that recommended rotation strategies to slow the development of resistance are not widely followed in practice.

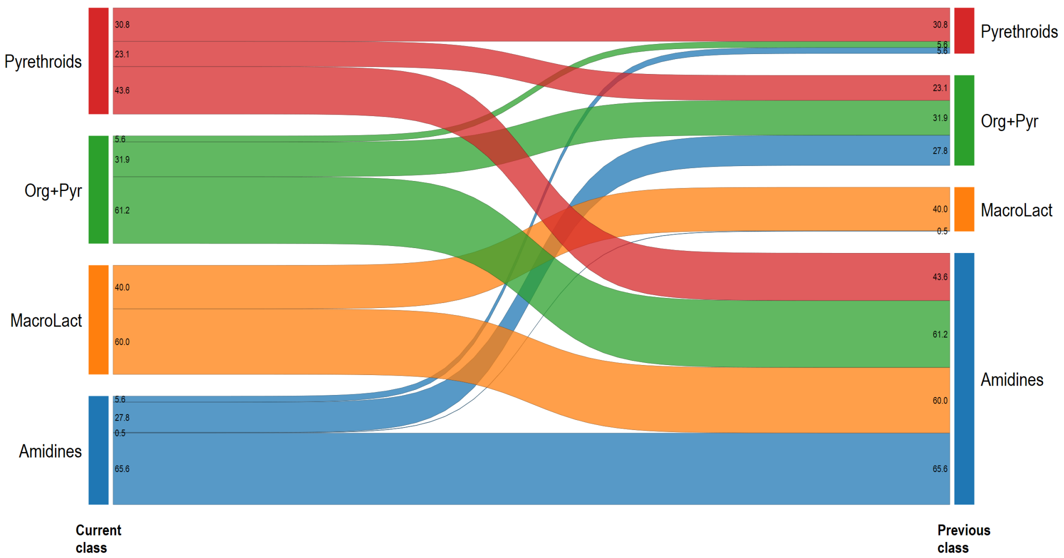


Figure 3: Shifts in acaricide use: comparison of current and previous product classes. The values shown in the diagram represent the percentage distribution of farmers within each current class according to the class they had used previously, illustrating how many farmers persisted within the same class versus those who switched from another class. Data are from the 2022 household survey. Farmers reported the products they were currently using and those used previously; these were classified into acaricide chemical classes. Orga+pyr is organophosphate plus pyrethroid co-formulations.

Taken together, these results suggest that although farmers are heavily invested in controlling ticks and tick borne diseases, the dominance of chemical control, coupled with frequent spraying and poor application and rotation practices, creates conditions that both raise costs and accelerate the development of resistance. The next subsection examines farmer knowledge and information use to better understand why on-farm practices diverge from recommended protocols.

5.2.1 Limited support for effective acaricide selection and rotation

Managing acaricide rotation requires technical knowledge that farmers are rarely expected to possess in well-supported systems. To assess how farmers navigate this complexity, we asked them about their decision-making process when switching between acaricides, focusing on where they obtain product recommendations. When asked what informed their decision to switch from one acaricide to another, farmers mentioned several sources of advice (Figure 4). The most common response was reliance on personal trial-and-error or on-farm experience (34%), followed by guidance from extension or veterinary officers (29%) and advice from other farmers or neighbors (24%). Only 16% of respondents cited drug shop attendants as an information source, underscoring the limited advisory role played by input suppliers. About 10% reported that they had never changed the type of acaricide used, while just 4% mentioned milk buyers as a source of information. These results highlight the fragmented and largely informal information environment within which farmers make tick control decisions, with minimal structured guidance from extension or market actors.

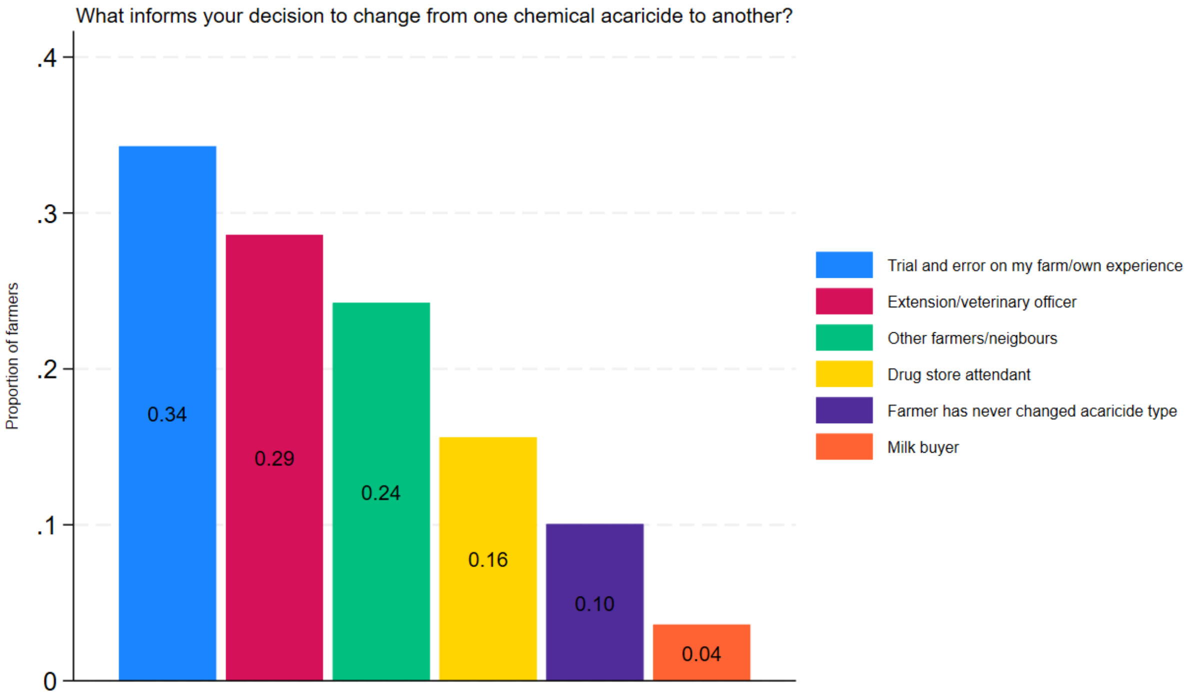


Figure 4: Proportion of farmers reporting different sources of advice when making decisions on which chemicals to use/change to

5.2.2 Limited farmer knowledge of acaricide classes

In the absence of institutional support, most farmers are left to make decisions about acaricide selection and use on their own. Using data from household surveys and exit interviews, we examine gaps in farmers' knowledge of different acaricide products and their respective chemical classes. Understanding these classes is essential for implementing effective rotation practices and managing resistance. We report statistics on two indicators of farmers' knowledge regarding product classification.

First, during exit interviews, farmers were asked to identify the class of the product they had just purchased. About 72% were unable to name the class, while only 26% correctly identified it. Second, in the household survey, farmers were asked which product—out of four options—would be most appropriate to rotate with for someone currently using Supona. The correct choice was the product belonging to a different mode-of-action class, as the remaining options were from the same class as Supona. Only 24% of farmers selected the correct rotation option.

5.2.3 Limited engagement with existing information materials

Information on the correct use of veterinary drugs is available to farmers through materials such as the National Drug Authority leaflet—which outlines acaricide classes and recommended rotation practices (Figure 6 in the Appendix)—and through product labels. However, engagement with these information sources appears limited. Only about 37% of farmers reported having seen the National Drug Authority leaflet, and among those, the vast majority (82%) encountered it at drug stores, with very few citing extension officers (4%) or veterinary officers (14%) as the source. Attention to drug labels was similarly low: nearly half of the farmers (47%) said they do not pay attention to label information, while 28% reported paying little attention and only 25% said they pay close attention. These findings underscore the limited reach and effectiveness of existing communication channels for promoting correct acaricide use.

Table 3: Farmer reported interactions with some of the existing information materials

	Proportion of farmers	N
Farmer has seen the NDA leaflet before	0.370	411
Location/place where farmer saw the NDA leaflet		
Drug store	0.816	152
Extension officer	0.039	152
Veterinary Officer	0.138	152
On a billboard	0.007	152
Attention to drug labels		
I do not pay attention to the labels on the drugs	0.474	411
I only pay little attention to the labels on the drugs	0.280	411
I pay more attention to the labels on the drugs	0.246	411

Note: Data from the exit interviews

5.3 Potential coordination challenges in tick management under extensive grazing systems

In the study area, most farmers—approximately 65%—practiced free-range grazing during both the dry and wet seasons. Grazing lands are extensive, with a median of 50 acres per farmer. Herd sizes are also large, averaging 70 animals (median 49), and improved breeds constitute a significant share of these herds. Such extensive grazing systems complicate tick management because herds of different households often intermingle on shared grazing lands and watering points, facilitating the spread of ticks across farms. Effective tick control under these conditions would require some degree of synchronized acaricide use.

Rotational grazing can disrupt tick life cycles and reduce infestation pressure, yet it remains uncommon among sampled farmers—only 35% reported it as their predominant production system. These production systems - large herds, open pastures, and a mix of susceptible improved breeds - create conditions that increase the risk of tick transmission and make coordinated resistance management increasingly important.

Table 4: Livestock production systems in the study area

	Mean	SD	Median	N
Free range grazing in the preceding dry season	0.647	0.478	1	926
Rotational grazing in the preceding dry season	0.353	0.478	0	926
Free range grazing in the preceding wet season	0.658	0.475	1	926
Rotational grazing in the preceding dry season	0.342	0.475	0	926
Farmer uses feed supplement	0.649	0.478	1	926
Available grazing area (acres)	70.0	61.0	50	926
Herd size	67.8	69.5	49	926
Number of non-improved breeds	8.3	31.6	0	926
Number of improved breeds	56.4	42.1	46	926
Animals comes into close proximity with those of neighbours	0.183	0.386	0	926

Note: Data from the household surveys in 2022, covering the last 12 months of production. Continuous variables have been winsorized at the 0th and 90th percentiles.

5.4 Input market imperfections

5.4.1 Farmer perceptions of product quality and input market performance

Farmers rely heavily on private input sellers for access to acaricides; however, input markets in these contexts often exhibit significant limitations that may constrain their effective use and contribute to the development of resistance. Concerns about product quality are common, and farmers' perceptions—whether accurate or not—play an important role in shaping behavior (Michelson et al., 2021).

We collected data on farmers' perceptions of acaricide quality and effectiveness during the household surveys. When asked to rate the effectiveness of the acaricides they were currently using, a majority of farmers (53%) described them as only somewhat effective, while 29% considered them effective and just 5% very effective (Table 5). About 12% viewed their products as not effective, and another 5% said they did not know. These perceptions suggest growing uncertainty about the reliability of available products.

When asked what they considered the main reason for acaricide failure, nearly 15% of farmers attributed it to counterfeit or poor-quality drugs, while smaller shares cited wrong application methods (7%), expired drugs (5%), and poor tick management by neighbors (11%). Few mentioned environmental or water-quality factors, and only 0.1% referred to witchcraft. A majority indicated that they did not know the cause. These patterns—high uncertainty and a tendency, among respondents with a view, to blame input quality—are consistent with credence-good information asymmetries that leave farmers unable to diagnose failure.

To further assess perceptions of product quality, farmers were asked to estimate how many of ten hypothetical buyers would obtain a good-quality acaricide if they purchased from different types of outlets. Responses highlight widespread uncertainty about drug quality and notable differences between rural and urban markets. On average, farmers believed that only about four out of ten buyers at village drug shops would receive a good-quality product, compared with about six out of ten in town shops (Table 5). These perceptions reinforce farmers' mistrust in the quality assurance of local veterinary drug outlets and their sense that product reliability varies across markets. Such beliefs, whether accurate or not, can influence purchasing patterns and may drive farmers to switch products frequently or experiment with unapproved alternatives.

Table 5: Farmer perceptions of product quality and input market performance

	Proportion of farmers	N
How effective do you rate the chemical acaricides you use?		
Not effective	0.124	916
Somewhat effective	0.529	916
Effective	0.289	916
Very effective	0.051	916
Do not know	0.005	916
In your opinion, what do you think is the main cause of tick resistance to the acaricides?		
Counterfeit drugs	0.148	926
Wrong application	0.069	926
Expired drugs	0.053	926
Poor tick management by neighbours	0.112	926
Witchcraft	0.001	926
Poor quality of water used in diluting the acaricides	0.042	926
Perceived percentage of farmers who would get good quality from a local shop	46.6	641
Perceived percentage of farmers who would get good quality in town	56.8	635

Note: Data from the household surveys in 2022, covering the last 12 months of production

5.4.2 Limited information flows between farmers and veterinary input sellers

Beyond concerns about product quality, we also assessed whether information is provided at the point of purchase. Earlier results showed that very few farmers during the household survey identified drug sellers as key sources of information when deciding on the products to use. To complement these findings, we use data from farmer exit interviews to examine the nature of farmer–seller interactions. These interviews provide insight into the type and extent of information exchanged at the point of purchase.

Results reveal limited advisory engagement between sellers and farmers (Table 6). A vast majority of farmers (98%) entered the shop already knowing which acaricide they intended to purchase, and almost all (98%) were able to buy the specific product they wanted. This pattern suggests that shop attendants respond primarily to existing farmer demand, with minimal effort to influence product choice or provide tailored advice. Similar dynamics have been documented in other input markets, such as hybrid maize in Kenya, where input sellers function mainly as distributors rather than advisors (Rutsaert, Donovan and Kimenju, 2021).

Only 28% of farmers reported that a drug seller in the store provided information about the brand, type, or chemical class of the acaricide. Slightly more (42%) said that the seller asked them questions before completing the sale—typically regarding the animal or herd, but rarely about current acaricide use or rotation practices. Among the subset of farmers who were asked questions, 17% said sellers inquired about the breed of animal, 46% about the quantity intended for purchase, 35% about the acaricide currently in use, and just 1% about their budget.

These findings indicate that most transactions occur with minimal discussion of proper product selection or use. The lack of diagnostic questioning and limited information provision highlight missed opportunities for shop attendants to guide appropriate chemical use. Combined with widespread farmer uncertainty about product effectiveness, these weak point-of-sale interactions further illustrate the information asymmetries that undermine effective tick control in liberalized input markets.

Table 6: Farmer-reported interactions with veterinary drug shop attendants at the point of sale

	Proportion of farmers	N
Did you already know the acaricide you wanted before getting into the shop?	0.976	411
Did you get to purchase the acaricide that you wanted?	0.978	411
Did anyone at the shop provide any information on the acaricide brands and class	0.282	411
Did anyone at the shop ask any questions before selling you the drug	0.419	403
Question asked		
Current acaricide used	0.357	168
Which breed of animal do you intent to use on	0.172	169
Budget for the acaricide	0.012	168
The quantity of the acaricide intending to purchase	0.464	168

Note: Data from the exit surveys with farmers

Table 7 summarizes the interactions between veterinary drug dealers and mystery shoppers who visited shops posing as farmers seeking acaricides. Results indicate limited advisory engagement between sellers and buyers. Only 2 percent of dealers asked whether the shopper had observed resistance to their current brand, and less than 6 percent inquired about spraying frequency. About 28 percent asked how long the product had been in use, and just 12 percent offered information on proper mixing or dilution. Fewer than 3 percent provided written guidance on dilution rates, while advice on application methods (6 percent) and safe handling (1 percent) was rare. Overall, these findings highlight minimal diagnostic questioning and limited provision of technical information at the point of sale, reinforcing the evidence of weak incentives and/or lack of capacity for effective farmer support within liberalized input markets.

Table 7: Interactions with mystery shoppers (enumerators posing as farmers)

	Proportion of farmers	N
Dealer asked wheher the shopper has observed resistance to current brand	0.021	747
Dealer asked shopper how long they have used the current acaricide	0.284	747
Dealer asked about the shoppers frequency of spraying	0.056	747
Dealer provided information on proper mixing/dilution	0.124	747
Dealer wrote on the drug information on dilution rates	0.028	747
Dealer adviced on proper methods of application	0.059	747
Dealer adviced on proper handling of acariciddes (safety)	0.008	747

Note: Data from the mystery shoppers. Each shop was visited three times, by three different mystery shoppers

5.5 Potential animal welfare, public health, and environmental externalities

Improper acaricide application, unsafe chemical combinations, and excessive dosing can create negative externalities that may affect animal health, human safety, and the broader environment. These risks are particularly important in the context of Uganda's expanding dairy sector, where maintaining product quality and consumer trust is critical for further expansion of the sub-sector. In smallholder settings, where chemical use is largely unmonitored, the boundary between managing tick pressure and generating unintended harm can easily be crossed.

Coping strategies adopted in response to declining acaricide effectiveness reveal worrying patterns of overuse and chemical misuse (Table 8). As noted earlier (Table 2), farmers spray more frequently than recommended, and many intensify these practices when the control outcomes decline. About 26% reported increasing the frequency of spraying, while 13% used higher-than-recommended concentrations. Such practices not only raise production costs but also accelerate resistance development and increase exposure risks for both humans and animals.

In addition to overuse, some farmers reported turning to unapproved or illicit products when conventional acaricides appear to be ineffective. Approximately 38% admitted using crop pesticides or herbicides for tick control, while 10% reported mixing different acaricides. Knowledge of such practices extends widely within farming communities: 64% of respondents said they were aware of other farmers using crop pesticides or other unregistered products for tick control. These responses suggest a growing sense of desperation to manage resistant ticks with limited information and weak regulatory oversight. Similarly, 55% of farmers interviewed during the exit surveys reported that they usually mix the acaricides they purchase with other chemicals, such as herbicides or pesticides.

Measuring the use of illicit tick control practices using surveys is hard. Indeed, during interviews, we noticed that farmers were reluctant to admit the use of so-called concoctions, where acaricides are mixed together insecticides/miticides such as *abamectin* and *acetamiprid* to increase effectiveness. Therefore, we included a list experiment in our survey as an alternative way to determine the share of farmers that use such practices. With a list experiment, respondents are never asked directly whether they use the practice. Instead, farmers are presented with a short list of common tick-control practices, and are simply asked to state how many of these they use, not which ones. Because they do not have to admit to any particular practice, respondents face much lower pressure to hide socially undesirable behaviour.

Concretely, we randomly divided respondents into two groups. The first, the ”direct” group, saw a card with seven common, non-sensitive tick control methods (for example: spraying with a hand pump, spraying with a motorized pump, use of a spray race, dipping, vaccination, etc.). They then indicated how many of these seven methods they had used in the past year. The second, ”veiled” group, saw the exact same card, with one additional practice added to the list: using mixtures of toxic non-veterinary chemicals (such as pesticides or insecticides) to control ticks. They were also asked how many practices on the card they had used.

Because assignment to the two groups was random, the difference in the average number of practices reported between the veiled group and the direct group provides an estimate of the share of farmers who used these toxic chemical mixtures. Importantly, at no stage do we learn whether any given individual uses the mixtures – only the presence of the additional item on the list allows us to estimate the prevalence of the practice in the sample. Using this method, we find that 16 percent of farmers, or almost 2 in every 10 farmers, have used mixtures of non-veterinary toxic chemicals to fight ticks in the preceding year.

The effects of these practices are beginning to emerge. Nearly one-third of farmers (27%) reported adverse effects in their herds associated with acaricide use. Reported symptoms include blindness (23%), skin disease (9%), coughing (5%), and eye irritation or tearing (7%). While self-reported, these cases are consistent with the growing use of off-label or degraded products and with unsafe application practices.

Beyond animal welfare, these behaviors carry potential public health and environmental implications. Direct exposure during chemical mixing and spraying can harm farm workers, while runoff and residue accumulation may contaminate soil, water, and pasture systems. About 18% of farmers reported that a household member had experienced adverse effects from acaricide use, and 7–9% reported cases of eye, skin, or respiratory irritation (Table 8). Though such reports require further investigation, they underscore the potential hazards of unregulated and unsupervised chemical use in smallholder settings.

At the output market level, these risks translate into food safety and trade concerns. The overuse of veterinary drugs and the use of unregulated or illicit products can leave residues in milk and meat, threatening consumer safety and undermining market confidence. In the absence of residue monitoring and enforcement systems, farmers prioritize immediate tick control and loss prevention over long-term safety considerations. When resistance emerges, many resort to unapproved products or intensify chemical use, potentially introducing residues into the food chain.

Overall, the evidence points to growing externalities associated with chemical misuse in tick control—which may negatively affect animal welfare, human health, environmental integrity, and the competitiveness of the dairy sector. Addressing these risks requires better understanding of the risks, stronger regulatory oversight, improved farmer training, and the development of residue monitoring systems that protect both producers and consumers.

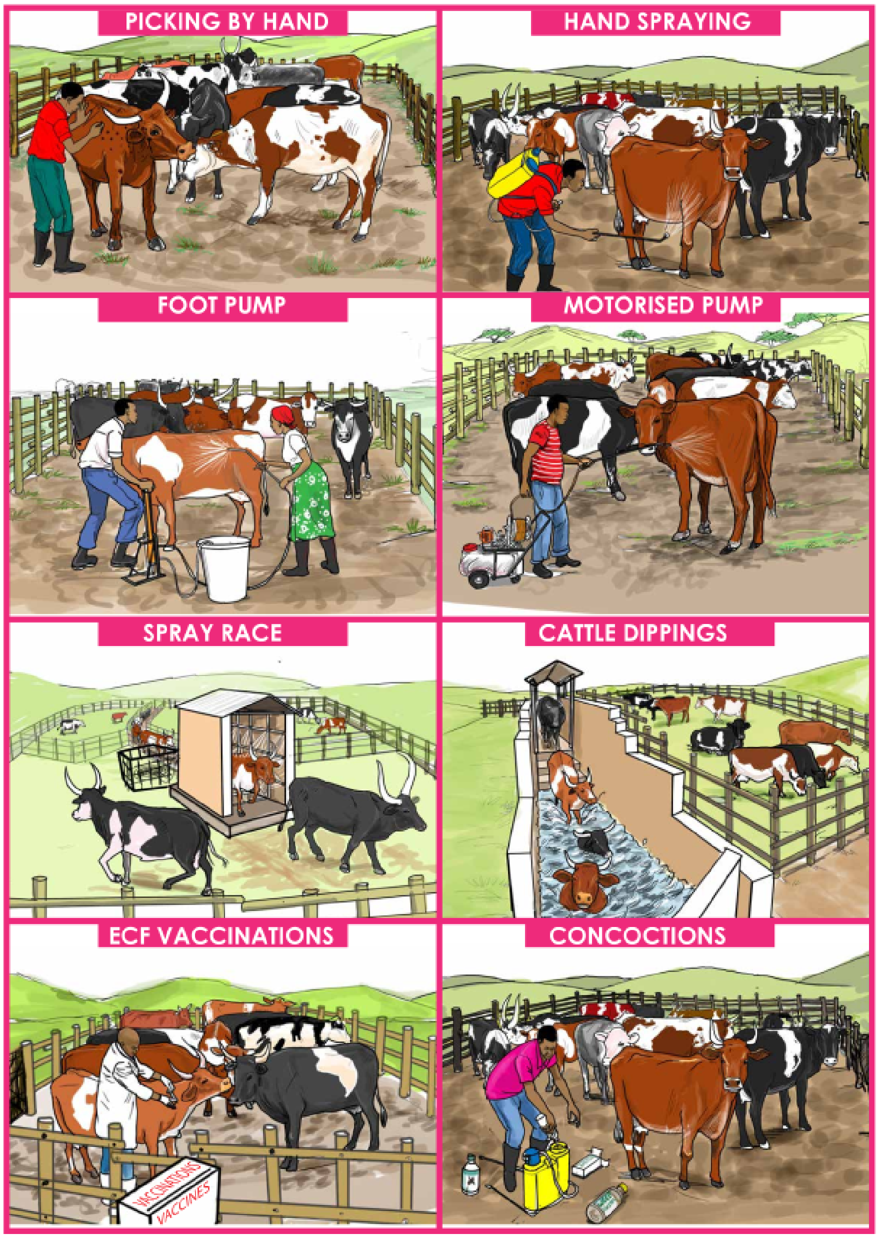


Figure 5: List experiment

Table 8: Farmer-reported coping practices and health effects

	Mean	SD	Median	N
Reported coping strategies to acaricide failures				
Mixing different acaricides	0.103	0.304	0	926
Use of a stronger dilution than recommended	0.134	0.341	0	926
Changing the type of acaricide	0.438	0.496	0	926
Increase frequency of spraying	0.258	0.438	0	926
Use of other chemicals, e.g. pesticides/herbicides	0.382	0.486	0	926
Vaccination of cattle against tick borne diseases	0.089	0.284	0	926
Strategies based on management eg zero grazing	0.009	0.093	0	926
Paddocking	0.045	0.208	0	926
Having more local breeds than exotics	0.006	0.080	0	926
Farmer aware of other farmers using concoctions	0.638	0.481	1	926
Reported cases associated with use of acaricides and other illicit chemicals				
Animal has suffered adverse effects due to acaricide use	0.271	0.445	0	926
Reported case of animal blindness	0.229	0.420	0	926
Reported case of skin disease in animals	0.090	0.286	0	926
Reported case of dizziness in animals	0.048	0.213	0	926
Reported case of animal coughing in animals	0.052	0.222	0	926
Reported case of animal eye tearing/itching	0.068	0.252	0	926
A person in the family has suffered adverse effects due to acaricide use	0.176	0.381	0	926
Reported case of blindness in humans	0.027	0.162	0	926
Reported case of human skin disease	0.066	0.248	0	926
Reported case of dizziness in humans	0.040	0.196	0	926
Reported case of coughing in humans	0.063	0.242	0	926
Reported case of eye problems in humans	0.081	0.273	0	926

Note: Data from the household surveys in 2022, covering the previous 12 months of production

6 Conclusion

This paper documents the systemic constraints that undermine effective, safe, and sustainable tick control in Uganda's smallholder dairy sector. Despite rapid growth and its central role in providing livelihoods and animal-source foods, the sector faces mounting challenges from ticks and tick-borne diseases ticks and tick borne diseases. Drawing on mixed methods including household surveys, list experiments, farmer exit interviews, and covert agro-vet shop audits, we show that the *de facto* farmer-led model of tick control is characterized by failures in information and coordination, imperfections in input markets, and weaknesses in regulation.

At the farm level, tick control is technically complex, requiring an understanding of acaricide classes, rotation protocols, and proper application methods that few farmers possess. Documented gaps in current application practices are likely contributing to the rise of resistance. Further research is needed to identify cost-effective ways of improving information delivery and extension modalities, including potential incentives for public extension systems and engagement of private sector service providers.

Farmers operate in a liberalized system where veterinary drug shops are the main source of acaricides, yet many are uncertain about the quality of products available. At the point of sale, little diagnostic questioning or technical guidance is provided, and transactions remain largely commercial rather than advisory. Further research is needed to better understand the constraints and opportunities within these markets, given the frequent contact between farmers and drug sellers. Evidence from other agricultural input markets suggests that addressing information gaps, incentive structures, and stocking risks influence agro-dealer behavior and farmer outcomes (Kariuki et al., 2025; Dar et al., 2024) resulting in better outcomes for farmers. Similar analyses are needed for veterinary inputs in the study context. Work on the quality, safety, and integrity of existing acaricide drugs is also critical.

The consequences of these systemic weaknesses extend well beyond the farm. As acaricides lose effectiveness, farmers increasingly resort to improvised and unsafe coping strategies—such as mixing chemicals or using crop pesticides on livestock. These practices create externalities that pose risks to animal welfare, food safety, public health, and the environment. While the literature documenting acaricide resistance in dairy cows has heretofore framed this primarily as an animal health problem, our analysis underscores that this is a development problem with much broader welfare and rural development implications. Without stronger institutional mechanisms for regulation and information support, these behaviors threaten to erode productivity gains and compromise the competitiveness of Uganda's dairy value chain, perhaps even foreclosing on economically important export market opportunities that the Ugandan dairy sector aspires to. Future research should assess the prevalence and risks of chemical residues in milk and meat value chains, as well as their broader environmental and human health implications.

Addressing these challenges will require integrated interventions that strengthen extension and regulatory systems, improve product labeling and quality control, and foster collective action at community level to ensure sustainable tick control. Future studies should also examine the behavioral and institutional mechanisms that shape chemical use decisions and evaluate interventions that promote coordinated, evidence-based resistance management. Beyond chemical control, greater attention should be given to alternative and sustainable methods, including vaccination and improved farmer uptake of integrated tick management practices. Only by addressing the systemic constraints identified here can Uganda—and similar dairy systems in the region—achieve sustainable livestock health alongside continued growth in animal-source food production.

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Appendix

The National Drug Authority (NDA) in Uganda provides detailed guidance on acaricide classes, emphasizing the importance of proper usage and rotation to prevent tick resistance. Below is an outline of the major acaricide classes used in Uganda, as recommended by the NDA, including their characteristics and recommended rotation practices:

1. Pyrethroids
    - Examples:Cypermethrin, Deltamethrin, Flumethrin
    - Mode of Action: Pyrethroids act on the nervous system of ticks, causing paralysis and death.
    - Advantages: Highly effective, quick action, and generally safe when used correctly.
    - Limitations: Overuse can lead to resistance, so they should be alternated with other classes.
    - Application Note: Pyrethroids can break down quickly in sunlight, so they're often applied more frequently.
2. Organophosphates
    - Examples: Chlorpyrifos, Diazinon, Coumaphos
    - Mode of Action: These disrupt enzyme functions in ticks, leading to nervous system failure.
    - Advantages: Effective against a wide range of tick species and often used when pyrethroids fail.
    - Limitations: Organophosphates are toxic to both animals and humans if mishandled, requiring careful use and protective measures.
    - Resistance Note: Rotate with other classes as ticks can develop resistance to organophosphates with prolonged use.

3. Amidines

    - Examples: Amitraz
    - Mode of Action: Alters nerve cell function, causing tick detachment and death.
    - Advantages: Amidines are particularly effective against ticks that may be resistant to pyrethroids or organophosphates.
    - Limitations: Prolonged use can lead to resistance, and they can be toxic to certain animals (e.g., horses and cats).
    - Application Advice: Best used in rotation and often recommended when resistance to other classes is suspected.

4. Macrocyclic Lactones

    - Examples: Ivermectin, Doramectin
    - Mode of Action: Interfere with nerve and muscle functions in ticks.
    - Advantages: Often administered as injectable treatments, making them convenient and reducing exposure risk.
    - Limitations: Costly compared to other classes, and misuse can contribute to resistance.
    - Special Uses: Effective against internal parasites as well, which can make them a good choice for integrated parasite control.

5. Phenylpyrazoles

    - Example: Fipronil
    - Mode of Action: Blocks chloride channels in ticks, leading to paralysis and death.
    - Advantages: Often effective against resistant tick strains.
    - Limitations: Typically used more in companion animals than livestock but can be part of rotation plans where applicable.

NATIONAL DRUG AUTHORITY

UNDERSTAND ACARICIDE CLASSIFICATION

A Key to Rotation Strategy and Responsible Acaricides use

Table showing Classes / Groups of Acaricides and some of their registered trade names in Uganda since 2020

CLASS AMIDINES AMITRAZ

Taktic
Almatix
Milbitraz
Bimatraz
Ecotik
Bovitroz
Norotraz
Vapcozin
Amitix

CLASS PYRETHROIDS

FLUMETHRIN
Bayticol pour-on
Bayticol 2%

ALFACYPERMETHRIN
Sypertix
Alfapor
Renegade 50 spray

CYPERMETHRIN
Award
Cypermethrin 10 EC
CyperGuard
Grenade

DELTAMETHRIN
Delta Guard
Vectocid

CLASS ORGANOPHOSPHATES

Supona

CLASS ORGANOPHOSPHATES +PYRETHROIDS

CHLORPYRIFOS + CYPERMETHRIN
DuoDip

ALFACYPERMETHRIN + CHLORFENVIPHOS
Protaid

CYPERMETHRIN + PIPERONYL
Secta-shampoo

CLASS MACROCYCLIC LACTONES

AVERMECTINS
Eprinomectin eg Eprizero

FIGHT TICKS

- Rotate (change) acaricides class/group as advised by veterinary professionals.
- Testing ticks before changing acanicides where, tick acanicide resistance has emerged
- Spray & Dip Animals as advised by veterinary professionals & Recommended by drug manufacturers.

Always seek Veterinary professional advice on acaracide mixing, spraying and dipping livestock in tick control

"Animal health is our noble concern"

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Figure 15: *Showing the different classes of acaricides on the Ugandan market. Under each class are the registered brands on the market*

VETERINARY MEDICINES UPDATES BULLETIN

Figure 6: Acaricide classifications by NDA

General NDA Recommendations for Farmers in Uganda

1. Rotation of Acaricides: Farmers should rotate acaricides every 3–6 months to avoid the buildup of resistance. For instance, after using pyrethroids, switch to organophosphates or amidines, and so on.

2. Follow Dosage Instructions: Proper dosage and application frequency, as specified on labels, are crucial. Under-dosing can encourage resistance, while overdosing may harm animals and handlers.

3. Protective Equipment: Always use gloves, masks, and aprons when handling acaricides to avoid direct contact and potential toxicity.

4. Consult Veterinarians: Work with veterinarians to monitor tick populations and adjust acaricide use as needed.
5. Environmental Considerations: Safely dispose of containers and avoid contamination of water sources.

For detailed information, including safe handling procedures and application techniques, you can check with the NDA or local veterinary offices in Uganda, which often distribute leaflets or guidelines on best practices for acaricide use.

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