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Challenges and stakeholder perspectives on livestock traceability systems in subtropical Botswana for improved food security and economic sustainability

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Abstract

This paper examines stakeholder perspectives on the challenges facing livestock traceability in Botswana, focusing on systemic, institutional, and usability constraints that hinder effective implementation. Using a mixed-methods design, the study collected quantitative survey data and qualitative interview narratives from 66 participants, including farmers, veterinary officers, and policy actors, across all nine administrative districts. An NVivo-based analysis revealed that the current Botswana Animal Identification and Traceability System (BAITS) is widely perceived as fragmented, inaccessible, and poorly adapted to local practices, particularly by older and less digitally literate farmers. Key concerns included unreliable infrastructure, lack of inter-institutional coordination, and limited user engagement. Despite these challenges, participants expressed interest in affordable technologies, localised training, and cross-sector integration. While this paper focuses on empirical insights, a separately published solution framework offers a technical response to the issues raised. This study provides a grounded, context-sensitive understanding of livestock traceability in sub-Saharan settings, offering policy and design recommendations for inclusive, interoperable systems.

Keywords: BAITS, data interoperability, ICT infrastructure constraints, policy and governance, RFID ear tags, smallholder inclusion, value chain transparency

1 Introduction

Animal traceability is implemented through devices such as RFID tags[1], boluses, electronic IDs, and ear tags equipped with various sensors and chips that gather essential data for animal identification and traceability (Bowling *et al.*, 2008, Zhao *et al.*, 2020, Pereira *et al.*, 2023). This data is then transmitted and stored in centralised databases. In Botswana, the Livestock Identification and Trace-back System (LITS) implementation began in 2001 under the Department of Veterinary Services (DVS) with government funding (Oladele & Jood, 2010). The government of Botswana outsourced the management of the LITS central database to local private companies, but these efforts were unsuccessful due to inadequate handling of the database's complexity, resulting in further delays and the loss of critical information. Originally established to ensure compliance with EU regulations, LITS employed a ceramic reticular bolus with an RFID microchip for cattle identification, linking data across various national sites including field stations, slaughterhouses, and border points. The system comprised two main subsystems: the core system which included the central database and its applications, and the remote data capture system which utilised RFID technology for real-time data collection.

Challenges with data collection led to the development of the Botswana Animal Information and Traceability System (BAITS) to improve record keeping and data management alongside LITS (Bowling *et al.*, 2008). BAITS utilises paired RFID-visual ear tags to monitor cattle throughout their lifespan, linking each animal to a farmer's account via a registered keeper ID issued by DVS (Government of Botswana, 2020; Government of Botswana, 2018). Calves must be tagged within three months of birth using approved dual-

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[1] E.g., wireless devices containing a microchip and an antenna which store and transmit data via radio waves, thereby enabling the automatic identification and tracking of objects

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identifier tags procured from Livestock Advisory Centres. While the electronic component can be read by scanners, routine events (such as registrations, movements/arrivals, ownership transfers, treatments, and mortalities) are typically recorded on the BAITS web/mobile platform or captured from paper forms by DVS where necessary (Government of Botswana, 2020; Government of Botswana, n.d.). For movement, sale, or slaughter, a DVS movement permit is required, with applications submitted online or through BAITS agents/BAITS cafés, ensuring that transactions remain regulated and traceable (Government of Botswana, 2020; Government of Botswana, n.d.).

Although these systems are in place, the management of the central database faced significant issues, such as delays in updating, which led to data inaccuracies and loss, complicating report generation and accessibility for farmers.

Despite the potential benefits of RFID in enhancing animal traceability and mitigating cattle rustling – a significant challenge yet to be fully addressed in Botswana – the integration of these technologies into effective management practices remained limited. The multiplicity of stakeholder-specific systems complicated the traceability process. Veterinarians and farmers use BAITS, the Botswana Meat Commission (BMC) uses an integration system, and the Matimela[2] office is developing a new system. This leads to fragmented and often incompatible data management efforts across the sector. However, an integrated and interoperable livestock traceability system could resolve these issues by consolidating stakeholder efforts into a unified framework. This would reduce costs, improve response times, and enhance the effectiveness of anti-theft measures.

In Botswana, several challenges in animal traceability are identified, including a lack of visibility within supply chains, making it difficult to track animal health, ownership, and location (Addo-Tenkorang *et al*., 2019). The high cost of GSM-based tracking systems limits their accessibility, reducing adoption rates and increasing risks like stock theft. Poor animal health management is exacerbated by the absence of affordable and reliable technology, while passive ear tags in free-range environments further complicate monitoring (Addo-Tenkorang *et al*., 2019). Outbreaks of foot-and-mouth disease (FMD) require significant resources for control and impact traceability. Wildlife conflicts in FMD-endemic areas also hinder effective livestock management (Bahta *et al*., 2023). Environmental factors like high temperatures and inefficiencies in traditional farming, including low off-take rates and high mortality rates, also reduce the effectiveness of traceability systems (Bahta *et al*., 2023). Overall, these issues highlight the need for improved infrastructure and technological solutions to support traceability (Mwanga *et al*., 2020).

Transhumance was traditionally practiced in Botswana, especially in regions like Ngamiland and the Okavango Delta. However, nowadays transhumance is no longer practiced. One major reason is land use policy. The Tribal Grazing Land Policy (TGLP) of 1975 and the National Policy on Agricultural Development (NPAD) of 1991 promoted fencing and privatisation of rangelands. These policies disrupted traditional systems where herders moved cattle between village, dry season, and wet season pastures (Behnke, 1985; Perkins, 1996). Another reason is the construction of veterinary cordon fences to control diseases like foot-and-mouth disease. These fences fragmented the landscape and blocked cattle movement routes (Hobbs *et al*., 2008). As a result, many pastoralists in Botswana, including the San, now practice sedentary grazing, which places increasing pressure on limited communal grazing areas and reduces ecological resilience (Hitchcock & Sapignoli, 2019). At the same time, it simplifies the process of tracking and monitoring livestock movements.

In other African countries, such as Kenya, Ethiopia, and Tanzania, animal traceability systems face challenges due to inadequate infrastructure and high costs associated with technologies like RFID, making adoption difficult for many farmers (Nkatekho, 2024). There is also a lack of regulation and oversight to enforce traceability practices, and limited stakeholder coordination further impedes progress (Nkatekho, 2024). In Kenya, the absence of proper animal identification methods affects disease surveillance and control, particularly for diseases like African swine fever and cysticercosis (Mutua *et al*., 2020). In Tanzania, a pilot study using the livestock identification and traceability system showed potential for tracking cattle, but accurate data collection, lack of incentives for adoption, and limited stakeholder coordination remain an issue (Mutua *et al*., 2018). The unreliable internet connectivity in rural areas complicates real-time data collection and monitoring, hindering the effectiveness of traceability efforts (Resti *et al*., 2024). Moreover, only a few recording tools have been implemented, emphasising the need for better systems to ensure food safety and animal movement regulation (Resti *et al*., 2024). These countries must address infrastructure gaps, resource allocation, and regulatory frameworks to improve animal traceability systems.

This study answered two research questions: 1) What are the perceived challenges of livestock traceability in Botswana according to the main stakeholders? 2) How do these stakeholders view these challenges?

[2]Matimela - the management of stray cattle in Setswana.

2 Materials and methods

2.1 Study area

The research was conducted across Botswana, a landlocked nation in the heart of Southern Africa. The country spans approximately 965 km from east to west and from north to south, with a distinctive eastern protrusion (Parsons, 2024). Botswana is renowned for its rich biodiversity and hosts a variety of wildlife, including fish, reptiles, mammals, amphibians, and birds. Historically, it has been recognised as a nation that rears cattle. The livestock population is primarily concentrated in the northern regions, benefiting from perennial rivers, hilly terrain in the hardveld[3], abundant water, and effective animal disease control measures that foster the raising of high-quality indigenous beef cattle. Botswana comprises nine administrative districts, namely Central, Kgatleng, Southern, South-East, Kgalagadi, Ghanzi, North-West, North-East, and Kweneng, as depicted in Fig. 1. The study involved site visits to farms and the offices of various organisations including the Ministry of Agricultural Development and Food Safety (MOA), the BMC, veterinary services, and local administrative authorities (Matimela), across all of these districts.

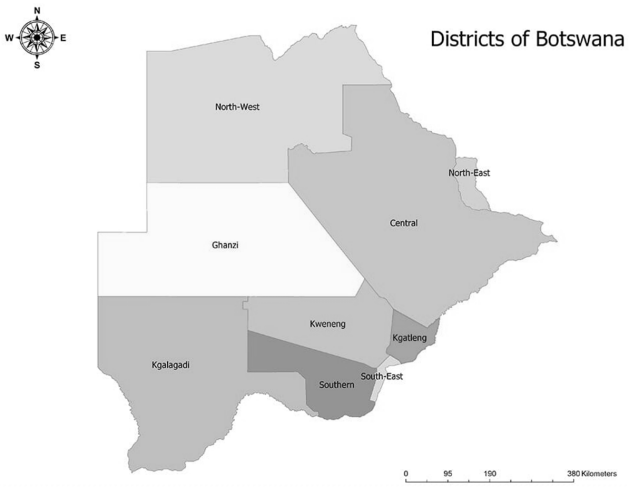

Fig. 1: *Districts of Botswana (Mappr, n.d.)*

2.2 Sampling, sample size, and selection of participants

The study utilised purposive stratified sampling across the nine districts of Botswana, treating each district as a separate stratum for sampling purposes. Participant selection was based on lists provided by government veterinary officials, with random selections made from these lists or through direct farm visits where lists were unavailable. The study aimed for a sample size of 60 participants to ensure data saturation without excessive redundancy, drawing on guidelines for achieving depth in qualitative and quantitative research. Ultimately, 66 participants were interviewed, including both farm owners and managers, ensuring diversity across stakeholder groups. Table 1 shows the distribution of the 66 participants across stakeholder groups.

Participants were drawn from five stakeholder categories: farmers (both farm owners and managers), veterinary professionals, representatives of the MOA, BMC officers, and local administrative authority personnel. Inclusion criteria required participants to be active in cattle farming, veterinary services, or BAITS support roles. Exclusion criteria included individuals with no experience or indirect involvement in livestock traceability. Participants were anonymised using role-based pseudonyms (e.g., FARMER5, VET2, MANAGER8) to protect identity while maintaining analytical clarity.

Table 1: *Distribution of the 66 participants over the five stakeholder groups.*

Stakeholder group	*Sample size*
Farmers and farm managers	42
MOA officers	5
BMC employees	1
Local administrative authority personnel	9
Veterinary professionals	9

The selection reflected a strategic focus on capturing a range of insights across operational, regulatory, and market domains. This approach aligns with methodological precedents in similar livestock traceability studies (Prinsloo & de Villiers, 2017).

2.3 Data collection

This study employed a concurrent triangulation mixed methods design, incorporating both qualitative and quantitative data collection to provide a comprehensive view of livestock traceability in Botswana (Cresswell & Plano Clark, 2018; Cresswell & Cresswell, 2022). An explanatory research design guided the structure of investigation and interpretation.

Ethical clearance (HREC-011) was granted by the research ethics committee at Botswana International University of Science and Technology. Research permits were also obtained from the MoA (DVS 7/4/1 VII (90)) and the

[3]Hardveld refers to areas of rocky, hilly terrain with more fertile soils and denser vegetation.

Ministry of Communications, Knowledge, and Technology (MCKT/1/11/1 I (38)).

Face-to-face semi-structured interviews were conducted in English and Setswana, depending on participant preference, to collect qualitative data, while structured questionnaires supported quantitative data gathering. This mixed-methods approach enabled the researchers to capture both measurable indicators and rich, contextual stakeholder experiences across all nine administrative districts of Botswana. The interview guide was developed in alignment with the principles of Interpretative Phenomenological Analysis (IPA) (Smith, 1996; Smith & Osborn, 2015; Smith *et al*., 2022), covering five themes and focus areas relevant to stakeholder engagement with livestock traceability systems (Table 2). The interview guide was designed to facilitate in-depth exploration of participants' lived experiences with livestock traceability systems.

Table 2: *Interview themes and corresponding focus areas used to guide semi-structured interviews, aligned with IPA principles.*

Themes	*Focus areas*
Experiences with traceability systems	First-hand use of BAITS, recordkeeping practices, and cattle monitoring tools
Barriers and constraints	Digital literacy, access to infrastructure, economic burden, and institutional inefficiencies
Ethical and cultural perspectives	Perceptions of fairness, data ownership, responsibility, and surveillance
Needs and recommendations	Policy, training, technology design, and community-based solutions
System use vs. non-use	Reasons for active or passive participation or non-participation in traceability systems

These themes, shown in Table 2, provided a framework for conducting semi-structured interviews, allowing participants to voice their personal insights while ensuring consistency across stakeholder groups. Each interview lasted between 45 and 90 minutes, was audio recorded, transcribed verbatim, and translated where necessary.

2.4 Data analysis

The study followed a concurrent triangulation mixed methods approach. This involved analysing quantitative and qualitative data separately before integrating them during the interpretation stage to provide a comprehensive understanding of stakeholder perspectives on livestock traceability in Botswana.

Quantitative data from structured questionnaires were entered into Microsoft Excel and analysed using descriptive statistical methods. Measures of central tendency, such as mean, median, and mode, were used to summarise demographic characteristics of participants and to reveal patterns in cattle theft incidents across Botswana's districts (Kothari, 2004; Marshall & Jonker, 2010; Yellapu, 2018). These statistical summaries provided context for interpreting qualitative findings, particularly in relation to geographic disparities, educational attainment, and stakeholder roles.

The qualitative component was grounded in a phenomenological methodology, specifically IPA (Smith, 1996; Smith & Osborn, 2015; Smith *et al*., 2022), complemented by a hybrid phenomenological approach developed by Alhazmi & Kaufmann (2022), and thematic analysis (Nowell *et al*., 2017). These frameworks enabled the researchers to explore not only what participants experienced but also how they interpreted those experiences in relation to Botswana's livestock traceability systems. IPA facilitated in-depth, idiographic exploration of participants' perceptions, particularly how they understood the role, function, and limitations of traceability systems in their daily practices. The hybrid phenomenological approach enriched the inquiry by combining descriptive insights into system usage patterns with interpretative understanding of socio-technical and cultural dynamics. This dual orientation allowed for the integration of detailed individual experiences with broader contextual meaning-making.

Semi-structured interview data were transcribed verbatim and imported into NVivo 12 for analysis (Welsh, 2002). IPA principles guided the initial coding process, with close attention paid to language use, emotional tone, and contextual nuance to capture participants' subjective meaning-making. Descriptive phenomenology supported this process by ensuring that emerging codes remained grounded in participants' lived realities, including challenges with BAITS, perceptions of fairness, digital exclusion, and institutional fragmentation. The analysis proceeded with multiple readings of each transcript to establish familiarity, followed by exploratory coding to identify key experiential and conceptual insights. Codes were then grouped into emerging themes and validated against the original transcripts for coherence and authenticity. Reflexivity was maintained throughout to minimise researcher bias and ensure alignment with participant meanings.

Following IPA-guided coding, thematic development employed axial coding techniques informed by grounded theory (Cresswell & Cresswell, 2022). Frequently cited concepts, such as "system", "cattle", "tag", and "record", were expanded into broader thematic categories including technological infrastructure, access and training, institutional coordination, and socio-cultural barriers. NVivo tools such as matrix coding queries, cluster analysis, and project maps were used to explore co-occurrence patterns and map relationships between stakeholder types, locations, and challenges

(AlYahmady & Alabri, 2013; Dollah *et al*., 2017; Jackson & Bazeley, 2019; Allsop *et al*., 2022). This layered analytical strategy allowed for the integration of individual meaning-making (via IPA) with cross-participant thematic synthesis, resulting in three superordinate domains: (1) lived experiences with traceability systems, (2) institutional, technical, and social barriers, and (3) forward-looking suggestions and system improvements. Thematic tables were developed to organise subthemes and illustrative quotations. The final analysis directly informed the ontology-driven framework (Mokgetse *et al*., 2024; 2025) and the policy recommendations presented in the conclusion of this paper.

3 Results

3.1 Results of quantitative analysis

The quantitative data offered contextual insight into stakeholder diversity and traceability system engagement across Botswana's districts. Participation was highest in Kgalagadi (23 %), Ghanzi (18 %), and Central (17 %), reflecting their prominence in cattle farming. Age-wise, the 45–54 group (27 %) and retirees over 60 (26 %) were the most involved, indicating that traceability is primarily managed by older individuals who also tend to own cattle.

A significant gender imbalance was observed, with men comprising 83.3 % of respondents – highlighting how sociocultural norms limit women's participation in system use. Furthermore, 45 % of participants had not completed secondary education, correlating with recurring usability challenges discussed in the interviews, particularly regarding English-only interfaces and technical complexity.

Cattle theft over a twelve-month period was notably high in Ghanzi (277 cases), Kgalagadi (209), and Kweneng (181), with recovery rates remaining low across districts. These patterns emphasise the importance of reliable, real-time traceability for theft prevention and legal recourse. Overall, these statistics frame the qualitative themes that follow, especially those concerning access barriers and institutional limitations.

3.2 Results of qualitative analysis

Results of qualitative analysis deepened our understanding of how stakeholders across Botswana experienced and interpreted the country's livestock traceability system. Drawing on interviews with farmers, veterinary officers, law enforcement, and Matimela staff, the qualitative analysis examined how concepts like "system", "tag", and "record" are embedded in everyday realities of cattle management. Through grounded theory-informed coding, co-occurrence analysis, and NVivo-based mapping, this section reveals key thematic relationships and institutional patterns that shape traceability implementation, access, and perceptions. The findings are presented in Subsections 3.2.1 and 3.2.2: first, a visual and relational mapping of key codes and their intersections; and second, a detailed thematic account structured around stakeholders' lived experiences.

3.2.1 Coding patterns and systemic relationships in stakeholder narratives

The qualitative component of this study generated insights into stakeholder experiences and perceptions regarding animal traceability in Botswana. Word frequency analysis using NVivo revealed commonly used terms such as "farmers", "farm", "system", "use", and "record", underscoring their centrality in stakeholder narratives. However, the analysis extended beyond simple keyword counts. Cluster analysis grouped semantically related items into thematic domains such as "operations", "tracking", and "information systems", providing a richer understanding of the institutional and technical barriers to traceability.

To further explore these themes, NVivo software was used to conduct a grounded theory-informed coding of interview transcripts (Cresswell & Cresswell, 2022). The interview transcripts were inductively coded, allowing themes and categories to emerge directly from stakeholder narratives without imposing a predefined coding framework. These themes and categories represented stakeholder concerns around livestock identification, data systems, and field-level practices. From this process, a set of prominent and analytically significant codes was identified, namely "animal", "cattle", "farm", "system", and "tag", which were then expanded through axial coding to include related concepts such as "permit", "record", "market", and "government". These final codes, listed in Table 3, were selected based on their thematic relevance and their role in shaping the ontology-driven framework developed in the next phase of this study (Mokgetse *et al*., 2024; 2025).

The use of matrix coding queries illuminated the relationships among central concepts like "cattle", "farm", "system", and "tag". These matrices enabled the examination of how different themes intersected across stakeholder types and geographical contexts, thus supporting the interpretation of systemic bottlenecks. For instance, the strong linkage between "cattle" and "farm" emphasised the critical role of local farm-level practices in ensuring traceability success. Likewise, the tight relationship between "system" and "tag" highlighted the dependence on effective identification technologies, a key challenge especially in rural areas with limited technical infrastructure.

Table 3: *Codes derived from qualitative interview analysis.*

Code	*Description*
Animal	General reference to livestock in the system, especially cattle
Cattle	Specific mentions of cattle breeds, movement, health, and tracking
Farm	References to farm infrastructure, practices, and management
System	Mentions of BAITS, LITS, or proposed system-related functionalities
Tag	References to RFID tags, ear tagging, and identification mechanisms
Vet	Involvement of veterinary services, permits, and animal health protocols
Police	Role of law enforcement in tracking and recovering stolen or stray animals
Permit	Movement permits and regulatory documentation processes
Government	Mentions of government role, policy, and system control
Traceability	Broad concept of tracking origin, movement, and ownership
Record	Discussion of data management, record keeping, and access to information
Market	Concerns related to cattle markets, trade, and economic implications
Location	Coded mentions of farm or kraal locations, district-specific issues
Sell	Selling cattle, price dynamics, and transaction documentation
BAITS	Specific references to the Botswana Animal Information and Traceability System

Further qualitative depth was achieved through NVivo's project mapping tools, as shown in Fig. 2. This map visualises the conceptual structure of Botswana's fragmented traceability ecosystem, drawing attention to the lack of interoperability across stakeholder systems. While veterinarians relied on BAITS, law enforcement and Matimela officers operated in parallel systems that were not linked, resulting in data silos and inefficiencies. Fig. 2 offers a high-level overview of the key traceability components including farming, records, markets, and systems.

This visual model revealed that stakeholders often operate in isolation, which severely hampers effective coordination. For example, when stray cattle are intercepted by police, the BAITS system lacks the functionality to rapidly identify ownership, leading to premature auctions at Matimela kraals. Such scenarios were repeatedly raised by interviewees as evidence of a system that failed to serve those on the ground. The map also showed that BAITS did not support real-time collaboration with other actors, such as BMC or district administrators, reinforcing the need for an integrated, multi-actor solution.

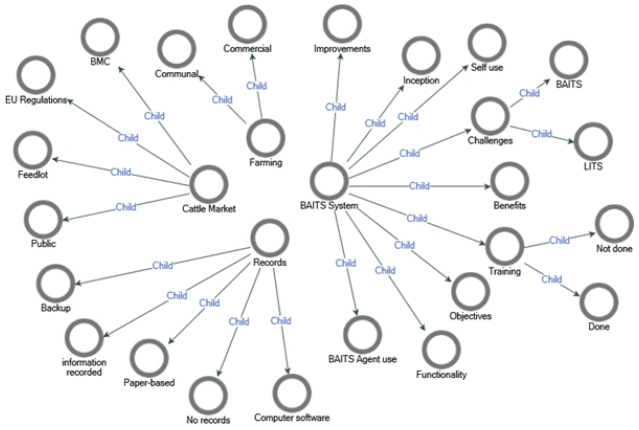

Fig. 2: *Project map of the four main components generated by NVivo software. This visual map illustrates the high-level structure of Botswana's animal traceability ecosystem as interpreted from coded qualitative data. The four main components ("farming", "record", "markets", and "traceability systems") are shown in relation to one another, highlighting the fragmented nature of current practices. The map reflects the absence of integration among stakeholder systems and reveals how disconnected processes undermine the effectiveness of livestock tracking and management.*

3.2.2 Thematic findings from IPA

Using IPA, we identified five superordinate themes capturing participants' lived experiences, perceptions, and meaning-making processes regarding the BAITS. Each superordinate theme is supported by two or more subthemes that reflect distinct but interrelated concerns expressed by participants, such as access limitations, system usability, institutional disconnection, technological challenges, socioeconomic constraints, and ethical considerations surrounding surveillance and fairness. Superordinate and subordinate themes emerging from IPA of stakeholder interviews on livestock traceability in Botswana are provided in the online supplement. Illustrative quotes are provided to contextualise and validate each subtheme, demonstrating the depth and diversity of participant perspectives.

The analysis revealed a complex web of systemic, institutional, and socioeconomic factors shaping the implementation of livestock traceability in Botswana. From the perspective of farmers, veterinary officers, and other stakeholders, the system was often perceived as costly, inaccessible, and overly reliant on external support. Cost and access limitations, alongside language and digital literacy barriers, continued to impede widespread adoption – particularly among older and small-scale farmers – while low motivation and limited ownership reflected a broader lack of engagement beyond transactional needs. Institutional disconnection, especially poor coordination between councils, police, veterinary officers, and Matimela units, exacerbated inefficiencies,

leaving regulatory frameworks fragmented and weakly enforced. Technical gaps such as unreliable connectivity, aging and inaccurate data, and system security flaws further undermined confidence in BAITS, while delays in market payments and unaffordable technology discourage participation. Despite this, many farmers express aspirations for affordable agri-tech solutions, surveillance tools, and community-based protection initiatives. However, the overarching sentiment reflects concerns over fairness, power imbalances, and the inequitable distribution of benefits – especially between commercial and communal farmers – indicating a critical need for inclusive reforms that build trust, improve digital access, and strengthen cross-institutional accountability.

4 Discussion

This study addressed two central research questions: (1) What are the perceived challenges of livestock traceability in Botswana according to the main stakeholders? (2) How do these stakeholders view these challenges?

4.1 Stakeholder perspectives on traceability functionality in Botswana

In response to the first question, the analysis revealed that stakeholders did not see traceability as a series of technical tasks but as an integrated socio-technical system shaped by the interplay of infrastructure, technology, and institutional coordination. The most prominent themes – "system", "tag", "farm", and "record" – were not only frequent but also deeply interconnected, suggesting that traceability's effectiveness is contingent on how these components interact.

For instance, the repeated co-occurrence of "system" and "tag" in interviews reflects the perception that identification technologies (e.g., RFID tags) cannot function in isolation – they must be embedded in systems that are operationally reliable, accessible in rural areas, and usable by non-technical stakeholders. This dependency illustrates a key shortcoming: the deployment of digital tools in contexts with weak enabling conditions like connectivity, maintenance, and local relevance. These interpretations align with IGAD (2019), which underscores that traceability systems often fail not due to lack of technology but due to institutional fragmentation and poor contextual fit.

Similarly, the link between "farm" and "record" highlights that the traceability system's credibility depends on accurate and timely local data entry, typically performed by farmers. However, farmers have expressed that the lack of real-time, user-friendly tools makes consistent recordkeeping difficult, especially where literacy and digital skills are low. This is supported by Mutua *et al*. (2018) who argue that smallholder-driven systems must prioritise decentralisation and usability to be sustainable.

Finally, the emphasis on "cattle rustling", "BAITS system", and "market" signals that stakeholders view traceability as more than logistics – it is a mechanism of economic protection, legal enforcement, and trade eligibility. Participants noted that without robust systems, they face financial loss, legal vulnerability, and exclusion from formal markets such as the BMC and EU export channels. These insights reframe traceability as a multidimensional tool, necessary not just for administration but for economic security and rule of law in rural communities.

4.2 Fragmented systems, marginalised users, and the imperative for context-aware digital traceability

Addressing the second research question, stakeholder dissatisfaction centred around two interconnected concerns: institutional fragmentation and user exclusion. Respondents described BAITS as unreliable, hard to use, and functionally disconnected from key actors like law enforcement and Matimela offices. These observations were visualised in the NVivo project maps, which revealed functional silos among institutions – each actor (veterinarians, police, district officials) operated in isolation with minimal data sharing. Such fragmentation led to slow or failed recovery of stolen animals, reinforcing perceptions that traceability systems are ineffective in real-world enforcement contexts. This mirrors regional concerns raised by the World Bank (2022) regarding poor institutional integration across livestock systems in Southern Africa.

Moreover, the data revealed significant usability and access barriers. Older farmers and those with limited education found the systems inaccessible due to complex interfaces and language barriers, while deeply rooted gender norms limited women's participation in traceability processes. According to the CIA World Factbook, Botswana's adult literacy rate stands at 88.5 % (CIA, 2015). While this figure reflects a relatively high national literacy rate, qualitative interviews revealed that many older and rural farmers struggle with system navigation, indicating that functional and digital literacy – not just basic literacy – are key barriers to traceability adoption. These challenges echo findings by Choung & Manamela (2018) that digital systems in rural Southern Africa often disregard the lived realities of marginalised users. Similarly, Mudege *et al*. (2015) show how entrenched gender norms restrict women's access to agricultural training – a dynamic clearly observed in Botswana, where female participation in traceability was notably low.

Synthesising these perspectives, a broader narrative emerges that stakeholders see traceability as a system of in-

terdependence – between users, technologies, and institutions. Codes such as "system", "record", and "market" were not merely frequent but conceptually central. Their thematic density reflects how stakeholders connect traceability to practical outcomes such as selling livestock legally, recovering lost animals, or complying with trade protocols. This interpretation aligns with critical insights from Aker *et al.* (2016) and Schroeder *et al.* (2021), who caution against top-down technology deployments in agriculture and advocate for user-informed, context-sensitive digital solutions that consider institutional constraints and local usage patterns.

4.3 Systemic misalignment of BAITS with customary livestock practices

The analysis of interviews demonstrated that BAITS, while designed for compliance and export readiness, often clashes with customary practices of livestock management, particularly in regions where traditional identification methods remain central to cattle rearing. Interviews across multiple districts demonstrated that the system requirements, such as strict movement permits, formal tagging, and digital system usage, are often misaligned with the realities of open-range, family-managed, and low-tech pastoral systems. Many farmers allow cattle to graze freely during the day and return on their own at night, a practice deeply embedded in communal livestock management. This directly conflicts with BAITS' requirement for precise and digitally logged movement records. FARMER34 (Southern District) noted:

We don't monitor the cattle when they go out of the farm for grazing. They roam freely during the day, and we just wait for them to come back on their own. That's how it's always been done here – there's no way to follow each one or track them constantly, especially without proper fencing or technology.

FARMER28 (Kweneng) explained:

We don't track the cattle once they leave the kraal. We just release them in the morning to go out and graze freely. Then we wait for them to come back on their own later in the day. They usually return to the borehole to drink water. That's how we've always done it – unless some don't return, and then we start looking for them.

These traditional grazing systems lack the infrastructure and control needed for BAITS to function reliably, particularly where cattle intermingle and tracking individual movements is impractical.

Farmers across regions continue to rely on colour, ear notches, and memory for identification, rather than the formal tagging methods required by the traceability system. For instance, FARMER19 (Kgalagadi) explained:

We identify our cattle by the ear tags and by experience – we know each animal's family line through traditional methods of identification

while MANAGER3 and FARMER16 (Kgalagadi) noted: *We keep track of each cow's history using its colour and the number we assign to it within the herd.*

While BAITS promotes standardised ear tagging, these tags can be easily removed or fall off, undermining traceability. As FARMER6 (Serowe, Central District) observed:

Tags fall off during bull fights or are cut off by thieves... I prefer the bolus as thieves could not get it off easily.

These testimonies illustrate a clear mismatch between traditional identification systems and the technological assumptions underpinning BAITS.

Engagement with BAITS is often minimal or passive among farmers who follow customary practices. Many rely on paper-based veterinary forms or delegate interactions with the system to BAITS agents. FARMER15 (Ghanzi), for instance, stated that he did not know anything about BAITS, despite managing 300 cows, instead using memory and physical identification. Another syndicate[4] farmer (FARMER14, Ghanzi) confirmed:

I don't keep any formal records. I farm the traditional way. I just use BAITS forms when ear tags or cattle sales are involved, but I've never used the system myself. I pay the BAITS café to handle everything for me.

These examples show that even large herd owners may remain digitally invisible, resulting in a disconnect between surface-level compliance (such as owning tagged animals) and actual participation in the digital traceability system.

This disconnection is further complicated by regulatory tensions between formal policy and customary norms. Legal enforcement of traceability requirements often faces resistance at the local level. As admitted by the BAITS coordinator in the MoA.

A calf is supposed to have an ear tag before six months after birth, but most farmers do not practice that. We do not take action because most farmers depend on cattle to feed their families and survive – to take them to jail or take their cattle will make them suffer. Being respectful to our elders is another hindrance; we can't go to old people or our relatives and easily enforce the law because of a complicated system our elders/relatives do not understand.

This highlights how legal enforcement of traceability is constrained by deep-rooted cultural norms and a reluctance to penalise elderly or economically vulnerable farmers. On

[4] In Botswana context, syndicate farms are communal holdings allocated to groups.

one hand, strict enforcement may alienate smallholders who lack the digital infrastructure or capacity to comply. On the other hand, lenient enforcement undermines the legitimacy and effectiveness of the national traceability system.

In many rural areas, informal community-based systems of surveillance and cooperation function as alternatives to digital traceability. Farmers often rely on neighbourhood watch groups or mutual networks to locate and recover lost or stolen animals. FARMER19 (Khalagadi) shared.

We have a neighbourhood watch. If our cow ends up with a neighbour's herd, they call us, and we go get it back.

These grassroots mechanisms are trusted, low-cost, and culturally embedded, in contrast to BAITS, which is often viewed as externally imposed and poorly adapted to local realities.

In summary, while BAITS plays a vital role in meeting export standards and enhancing national-level livestock data systems, it frequently conflicts with the communal and open-grazing practices that characterise much of Botswana's traditional cattle farming. Its dependence on digital infrastructure, formalised movement control, and standardised identification procedures contrasts sharply with memory-based management, shared pastures, and informal cooperation networks. Bridging this systemic gap will require culturally sensitive adaptation of BAITS – such as supporting hybrid identification methods, improving offline usability, and expanding participatory training – in order to ensure that small-scale and traditional farmers are not excluded from the benefits of traceability and market access.

5 Conclusion

Livestock traceability in Botswana is best understood as an interdependent socio-technical system whose performance depends less on the nominal presence of tools such as BAITS or RFID than on how well those tools are aligned with rural practice, coordinated across institutions, and usable in everyday conditions. The evidence from diverse stakeholder accounts indicates that gaps commonly attributed to users (i.e., age, literacy, language, cost) are in fact design and governance issues. Traceability becomes meaningful when technologies are offline-capable, affordable, and simple enough to be operated by non-literate or elderly farmers, and when they are embedded in responsive, interconnected institutions spanning veterinary services, BMC, Matimela, and law enforcement with coherent processes for registration, movement control, theft reporting, and recovery. Reframing success in this way shifts emphasis from technology roll-out to system alignment: the problem is not merely the absence of tags or databases, but weak interoperability, fragile connectivity, and workflows that do not match how farming is currently done.

The practical implications are therefore as follows: (1) to prioritise real-time data sharing and mutually recognised enforcement protocols across agencies, (2) to deliver low-data, Setswana-supported mobile workflows that reduce cognitive and administrative burden, and (3) to build on existing intermediaries and community networks (e.g., BAITS cafés, neighbourhood watch groups, respected local brokers) rather than trying to replace them. Affordability matters both at entry (registration, tags, first phone or reader) and in use (data, travel, time lost to queues and downtimes). Addressing these challenges and barriers will not only broaden participation among smallholders but also improve data completeness and timeliness, which are preconditions for credible certification and export readiness. Trust will follow when farmers see faster resolutions of theft and movement permits, fewer system outages, clearer responsibilities, and feedback loops that incorporate user reports into visible fixes.

These conclusions remain bounded by the study's qualitative, self-reported evidence base, uneven district representation, and cattle-specific focus. The immediate next step is to field-test user-informed prototypes under real operating conditions, combining usage analytics with qualitative feedback and extending to other species where appropriate. Our related ontology-driven solution framework (Mokgetse *et al*., 2024; 2025) provides a concrete pathway for integrating data standards, role-based access, and interoperability across agencies while supporting offline-first operation and multilingual interfaces. Rigorous, regionally tailored pilots that apply this framework – preferably co-designed with end-users and evaluated against adoption, data quality, enforcement responsiveness, and theft-recovery outcomes – will indicate what traceability system configurations are scalable, trusted, and sustainable for Botswana's diverse rural communities.

Conflict of interest

The authors have no conflict of interest to declare.

Data availability statement

The anonymised qualitative interview data that supports the findings of this study is shared on Figshare (https://doi.org/10.6084/m9.figshare.30173584.v1). The table presenting the superordinate and subordinate themes emerging from the IPA of stakeholder interviews on livestock traceability in Botswana, including verbatim quotations, is available as an online supplement on the article's landing page at https://doi.org/10.17170/kobra-2025112411679 .

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