Matete G O , Maritim W, Muchemi G, Maingi N, Gathuma J M and Ogara W (2010). Long-term performance of electronic identification devices and model traceability system for cattle under pastoral production systems of Kenya. *Livestock Research for Rural Development. Volume 22, Article #181.*

http://www.lrrd.org/lrrd22/10/mate22181.htm

*** Department of Veterinary Public Health, Pharmacology and Toxicology, University of Nairobi P.O Box 30197, Nairobi, Kenya**
george.matete@gmail.com
**** Ministry of Livestock Development P.O Kabete 00625 Kangemi, Nairobi, Kenya**
***** Department of Veterinary Pathology and Parasitology, University of Nairobi, P.O Box 30197, Nairobi, Kenya**

Abstract

The readability of two different types of electronic identifiers (EID) were evaluated under pastoral production system in North-Eastern Kenya. Physical verification and reading was done at day 0, and-1, 2, 4, 8 and 12 months respectively on a total of 1943 beef cattle of which 934 were tagged using ear button tags and 1009 with rumen boluses. The retention rates were recorded and readability determined using a hand-held reader and subsequently compared using a non parametric survival analysis.

The results showed that, rumen boluses were more effective with retention and readability of 100% after the one-year period. The retention rate for ear button tags deteriorated after day 120 to 94.6%. This implied that rumen boluses are safe and tamper-proof and are thus recommended for use in pastoral production systems. When tested within the model Livestock Identification and Traceability System (LITS), the use of RFID identifiers were able to substantially contribute to better record keeping, and proof of credible livestock certification. However, due to cost considerations, undertaking a benefit-cost analysis and provisional analysis of the institutional and organisational infrastructure may be critical for successful implementation.

Keywords: livestock identification, radio frequency identification devices, traceability system

Introduction

Lack of good record keeping systems has limited the export of animals from pastoral production systems in the horn of Africa. Traceability and permanent identification of livestock has evolved as one of the requirements in the global trade in beef (Schwägele 2005, Smith et al 2005). Electronic identification provides one such contemporary mechanism but its widespread use in Africa has been rather limited. In Kenya, after the outbreak of Rift Valley Fever (RVF) in 2006/2007 and the subsequent bans in live animal trade, it was evident that individual animal information management system was important to trace potentially infected animals to their origin.

The trial of electronic tags and a model Livestock Identification and Traceability System (LITS) was an effort by the Kenyan Veterinary Services Department (VSD) to prove credibility of her livestock certification procedures. Electronic identifier were suggested as useful in facilitating the mandatory registration and traceability of individual animals in pastoral areas through a reduction in labour costs, increased data accuracy, improved information sharing between the relevant bodies, better tracing and tracking, better space utilization during storage, automatic asset management, reduced stock-out in retailers, improved customer service and lower cost of inventory (Tajima 2007, Shanahan et al 2009).

This paper reports on the technical applicability (effectiveness, robustness and ease of use) of RFID identifiers in the pastoral cattle production systems in the north-eastern and coastal regions of Kenya. In addition, it evaluates the effectiveness of electronic identifiers in the capture and transfer of data to the local and central data bases.

Materials and methods

Study site

The study was implemented in selected areas along the cattle marketing chain from North-Eastern to the Coast province of Kenya i.e. Garissa livestock market, Chakama Ranch in Malindi District, Taru Ranch in Taita District, Mombasa export terminus and KMC Athi river (Figure 1).

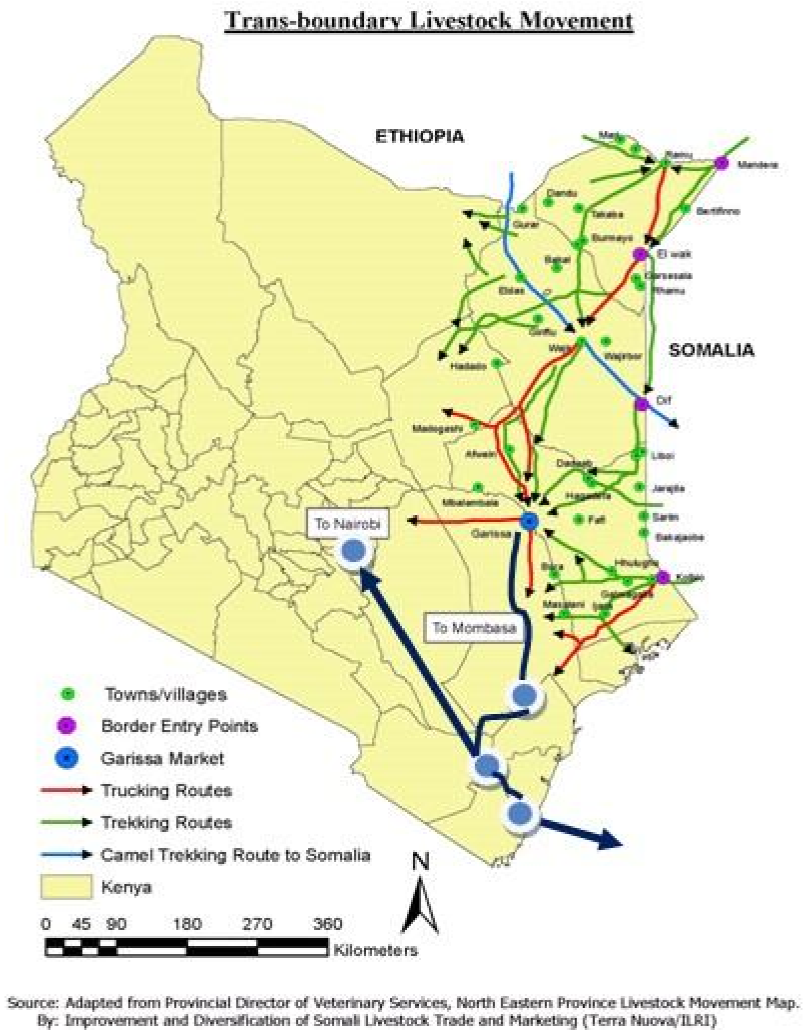

Figure 1. Selected study sites in Kenya as part of the Trans-boundary livestock movement route

The area chosen was the tail-end of the marketing chain with pastoral livestock originating from North-Eastern Kenya, Central and Southern Somalia coalescing in the Garissa market. On average 1000 heads of cattle sold in Garissa market every week are trekked to the Coast.

Sampling of traders and cattle

Four livestock traders cum ranchers' were selected from the membership of the Livestock Traders marketing society of Kenya (LTMS-K) in order to participate in the study. Those selected were involved in trekking large groups of cattle to the coastal ranches and also had ready money available to purchase cattle. Those identified as willing to participate were asked to commit themselves to complying with relevant veterinary procedures. As an incentive, the veterinary department waived cost of CBPP testing for participating traders. Subsequently, 1943 cattle (approximately 2 % of cattle purchased and trekked to the Coastal ranches over a 12-months period) were purposively selected and tagged with either of the two types of tags systematically. 934 cattle were assigned to ear button tags and 1009 assigned to rumen boluses. The majority of cattle were tagged at Garissa market, Chakama ranch in Malindi and a small number within the coastal ranches.

Whenever trade cattle were consigned to the market, clinical inspection and mouthing of individual animals detect clinical signs of FMD was done. Suspected cases were removed from the market and handled appropriately. The cattle purchased for trekking and fattening were sero-tested for CBPP. Those found free of CBPP antibodies had either one type of RFID tag applied, the animal registered and data collected transferred by synchronisation with the central database at the end of the day's operation. The hot iron brand P-1 was subsequently applied and the process of facilitating movement permits completed (inspection of the no objection and provision of movement permits) prior to dispatch. In order to ensure reliability of the RFID traceability system, automatic reading and recording of data were performed from a single lane crush and with an eye on the expected count of livestock in each instance. In the case of disparity in the actual count versus the expected count, an explanation was immediately sought to establish the cause.

Design, testing and deployment of the data collection and transmission system

A LITS system developed that was capable of capturing pertinent animal and user data individually and on synchronisation transfer the same to the central database and consequently to local databases further up the chain. It was able to use the electronic tags as clear, easily readable, low-cost and relatively durable means of identification and transfer it together with the attached auxiliary data too a recording database with minimum error (Pinna et al 2006). The final dataset comprised the unique identifier together with its corresponding series of true records of its history as it moves along the market value chain. The final dataset comprised the unique identifier together with its corresponding series of true records of its history as it moves along the market value chain (Figure 2).

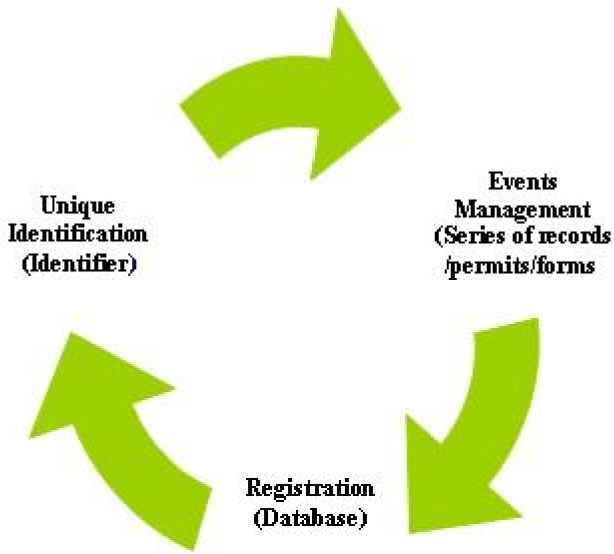

Figure 2. Diagrammatic illustration of the definition of Traceability

The system was able to establish details to help trace every movement event for an individual animal, when it occurred, what was done during the movement, how it was done, and who did it and where the person can be found (ICAR 2004; 2009).

Using the designed LITS model, practice/dummy run on the system was carried out at the KMC - Athi River export standard abattoir over a two-month period to test the capability of LITS to capture relevant data required to prove certification procedures. The dry-run was used to identify and address software failures and eliminate such prior to the final deployment at remote field sites. It involved the insertion of rumen boluses into cattle at the receiving area of the abattoir. This was followed by the registration of the animals, weighing before entry into the slaughter and bolus recovery process. It demonstrated understand how the LITS modules could be operationalized at field level.

Deployment of equipment and training at field level was carried out on a site-by-site basis. The training on effective use of the LITS system was guided by Standard Operating Procedures (SOP's) which provided recommendations on identification, reading, recovery, data recording and transmission of data and helped to avoid mistakes by the system operators.

Whenever trade cattle were consigned to the market, clinical inspection and mouthing of individual animals detect clinical signs of FMD was done. Suspected cases were removed from the market and handled appropriately. The cattle purchased for trekking and fattening were sero-tested for CBPP. Those found free of CBPP antibodies had either one type (rumen boluses or ear button) of RFID tag applied, the animal registered and data collected transferred by synchronisation with the central database at the end of the day's operation. The hot iron brand P-1 was subsequently applied and the process of facilitation movement permits completed (inspection of the no objection and provision of movement permits) prior to dispatch. In order to ensure reliability of the RFID traceability system, automatic reading and recording of data was performed from a single lane crush and with an eye on the expected count of livestock in each instance. In the case of disparity in the actual count versus the expected count, an explanation was immediately sought to establish the cause.

Application and monitoring of cattle identifiers

Rumen bolus

Each bolus was read immediately before administration to check for possible breakages or reading failures during tagging. A trained operator then administered the boluses using an adapted balling gun (Allflex®). Briefly, with each animal properly restrained, a metallic balling gun was introduced laterally as far as the end of the tongue while holding the diastema. The bolus was deposited into the bottom of oropharyngeal region in order to stimulate involuntary deglutition (Carné et al 2009 a,b). A second reading of the electronic tag was then performed using a directional caudo-cranial sweep behind the left front leg of the animal using the hand-held stick readers at 1, 30, 60 days, 8 months and 1 year according to the "Guide Procedures of the IDEA Project" (Caja et al 1999, Ribó et al 1999, Ghirardi et al 2006).

Ear tags

Similarly, each ear button tag was read immediately before tagging to check for possible breakages or reading failures. Ear button tag was then applied to the middle of the left ear at one third the distance from the ear base using a standard trigger applicator recommended by the manufacturer, but with the plastic tip removed (Universal Total Tagger, Allflex® Europe). The "Female" piece was located on the internal side of the ear. The applicator was sterilised using alcohol between each insertion. Reading was done by pointing the wand to the ear tag at a minimum distance of 12-20 cm. At least five readings were done for each tag over a one year period.

Recording and transmission of data into the central database

Physical verification and reading was done at day 0 and 1, 2, 4, 8 and 12 months, respectively with the timing chosen to coincide with periods of regular livestock monitoring by the veterinary department personnel. Registration involved the transfer of the unique identification number within the tag via a stick reader (middleware) to the LITS - compliant computer. Ancillary data such as trader names, origin of cattle and grade were subsequently entered into the relevant windows using the drop down menus.

Chakama ranch the staging post located in Malindi District, Coast Province was site of verification one month after the initial registration. When cattle reached this ranch the operations included new registrations, receiving then health and dispatch modules. An initial synchronization was also used to confirm presence of data on the animals registered in Garissa. The animals were again clinically inspected, physically mouthed for FMD and serologically tested for CBPP. Serological testing was done at least 21 days after the initial test had been done. Only animals that passed the second CBPP test were branded P-2. In addition, the cattle were treated for trypanosomosis, de-wormed and vaccinated for blackquarter and anthrax. At the end of the process, the reports of various operations were uploaded to the central database through synchronization. Animals passing the P-2 test were released and dispatched to enter into the coastal ranches.

At the coastal ranches animals were received and cleansed (sprayed for ticks and dewormed) using the LITS standard operating procedures. Cleansing involved treatment and fattening of the animals. One month to slaughter or export tests for transboundary diseases such as FMD and RVF were also performed on individual animals.

At the export abattoir, the cattle were received and the accompanying documents inspected and verified before offloading. They were consigned to the holding yard where clinical inspection was done for 24 hours. Each animal was then individually identified by the RFID identifiers, ear tag and mob number as they were being individually weighed. The cattle were then washed, stunned and slaughtered. Upon slaughter, the VSD meat hygiene personnel recovered the respective identifying devices and also linked them with the rest of the carcass at post-mortem examination. After overnight chilling the carcasses were graded.

Records of carcass grade, post mortem findings and the individual identification number were linked to the traceability system and transferred to the central database. The system modules used at the abattoir included those for receiving animals, health and slaughter. This was one of the exit points where the boluses were flagged off the system and recovered for recycling. All boluses collected at the abattoir were sent back to the VSD headquarters for sterilisation and redistribution. All ear tags were discarded.

Animals meant for export were dispatched from the Kilindini Port. Individual RFID identification numbers of cattle entering the ship were flagged off the system using the export module.

Data analysis and evaluation of traceability data

The for Statistical Package for Social Scientists (SPSS) System (v. 17) was used to make inference on the different parameters influencing the performance of LITS and evaluate technical applicability and tag reading. This included a determination of tag losses, electronic failures and readability were analysed on the basis of the categorical nature of these variables. This analysis permitted the comparison of the longitudinal readability of ID devices without excluding right censored data (data from animals that left the study before a device failed) (Cantor 2003, Kleinbaum and Klein 2005). Verification for the survival of tags was registered as interval data since continuous monitoring was impossible.

Results of field implementation of electronic livestock identification

Use of RFID tags

The proportions of cattle tagged according to breeds were Borana (47%), Surco (34%), Daura (15%), Small East African Zebu (3%) and Gazara (1%). Of these, 64% of the cattle were tagged in Chakama ranch (Malindi District) after the batches were consolidated with cattle from smaller markets like Ijara and Tana River. Thirty-five percent were tagged in Garissa and an experimental group of weaned animals (1%) born and reared exclusively at the coastal ranches were also tagged in Kwale. The age groups of tagged cattle varied from mature, 4to7 years (54%), immature, 1 to 3 years (44%) and young (1%) while their grades were Primo thus first class (50%); Secundo thus. second class (47%) and Goroba thus. third class (3%). The four traders who were members of the LTMS-K provided 51%, 17%, 16%, and 16% of the cattle tagged respectively.

Tag readability

Both types of tags had a high readability (Table 1), but when the two types of tags were compared a number of problems were observed with the ear button tag, which included loses and breakages.

Table 1. Outcome of tag readings during the study

Tag type and time	Readability of RFID tag types				
	Ear button tag				
	Day 0	One month	2 months	Six months	>eight months
Successful readings, %	99	99.20	98.30	97.40	94.60
Electronic tag lost and not read	2/934	8/934	16/934	25/934	50/934
Electronic tag broken	0	0	0	0	0
Readers failed to function.	2/934	8/934	16/934	25/934	37/934
Animal not present and therefore reading not performed	0	30	14	22	0
Tag type and time	**Rumen bolus**				
	Day 0	**One month**	**2 months**	**Six months**	**>eight months**
Successful readings, %	100	100	100	100	100
Electronic tag lost and not read	0	0	0	0	0
Electronic tag broken	0	0	0	0	0
Readers failed to function	0	0	0	0	0
Animal not present and therefore reading not performed	0	2	0	10	0

Both types of tags had a high readability, but when the two types of tags were compared a number of problems were observed with the ear button tag, which included loses and breakages.

The number of cattle identified per day per tagging team varied marginally between ndividual operators. The tagging efficiency ("number of animals/day") was dependent on the type of tag as well as the quality of the crush used to restrain cattle. The time spent to apply tags averaged 1.5 minutes for ear tags and 3.5 minutes for boluses respectively. On average a total of 250 cattle (with a range of 120-300) were identified/day/ tagging team. This time included that spent in sampling blood from the tail vein and mouthing for FMD.

The average tag losses were aggregated and causes recorded. The common causes included ear infections, predation and death due to disease. The most important was losses of ear button tags due to ear infections evidenced by a hole on the ear. These were less than 5 % although the likelihood of losses increased after 120 days. Only one button tag failed to read before the end of 120 days while 50 ear button tags were lost during the same period. It indicates that to rumen boluses, up to 6% of RFID ear button tags were lost under the pastoral production systems. This was attributed to the tags being caught in the bushes as cattle moved within the harsh terrain. During the same period, no loss of rumen bolus was noted. The ear button tags while exhibiting readability of 100%, had losses of nearly 6%, falling short of the International Committee on Animal Recording (ICAR) recommendations. Figure 3 compares the survival distribution of the electronic tags.

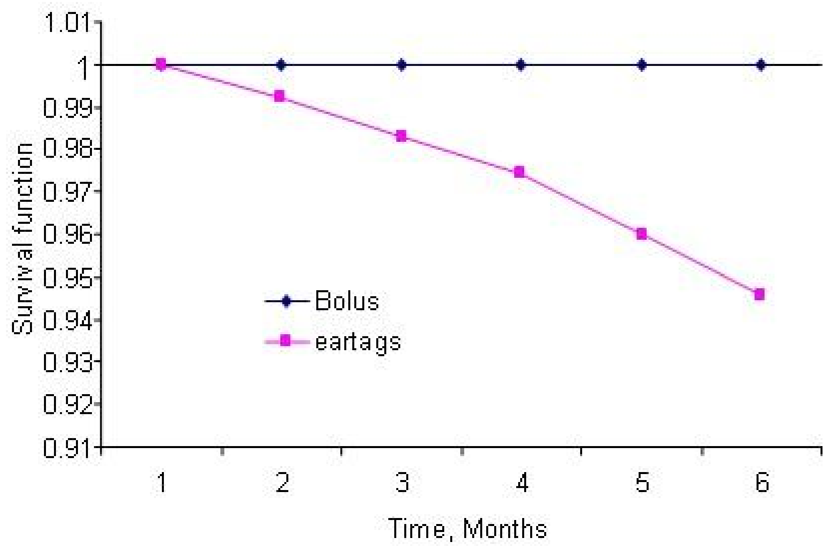

Figure 3. Survival distribution function of electronic tags verses body site

Function of the Model LITS

Figure 4 provides a summary of how LITS functions at field level. It illustrates its ability to follow a single animal consistently, combine them into a single batch or divide a single herd into different batches as well as identify whether the individual animal was eliminated from the system either through slaughter or export.

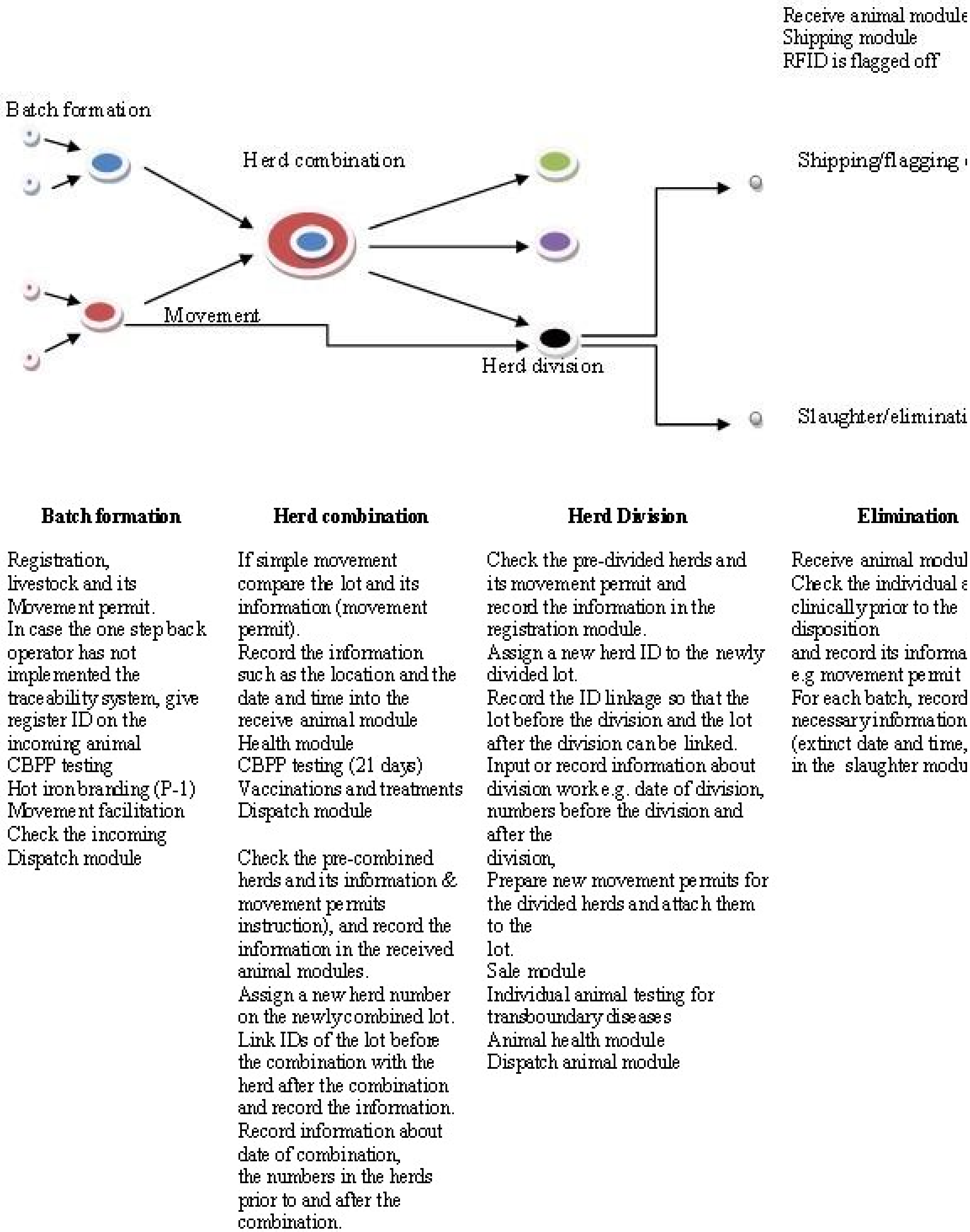

Figure 4. Tracking of cattle in pastoral areas

Constraints to implementation

Five broad areas of constraints namely technology (middleware), human resource capacity, software issues, shortfalls in the traceability system and market infrastructure were identified.

Technology

Failure of the middleware (reader cap) to transmit data to the LITS computer was the main problem encountered during the study. This failure was exhibited as electromagnetic interference (noise), while operating the RFID readers. The interference was generally attributed to electrical or mechanical interference with the readers, set-up and technology compatibility issues. This resulted in an inability to transfer the RFID numbers to the computers using affected readers. Such problems were either addressed by setting up a paper back-up of the RFID numbers, installing Opto Isolators and providing backup readers.

In general, it was evident that most of the technology issues (hardware, software, scanning, application of tags) were associated with the initial implementation process. These included: inappropriate application of ear button tags; software compatibility; due to poor General Packet Radio Service (GPRS) connectivity to the central database delaying synchronisation and frequent power outages.

Human resource capacity

Computer knowledge amongst the veterinary personnel varied considerably. The elements of human error included wrong application of ear button tags, failure to synchronise the databases either before or after the data entry procedure, data entry errors; forgetting to charge equipment or leaving vital components of the system at the base while travelling to the field.

However, SOPs were used as one of the options of reducing human errors during the study. In addition, carrying a soft copy backup of the final database and uploading it manually to the central database solved this problem.

Software

Data problems arose from issues related to the software. These generally fell into two categories: software incompatibility and confusion arising from outputs. Software compatibility problems were with: livestock management procedures; hardware; LITS systems errors in software design; and inadequate testing before deployment;

Confusion arising from outputs was due to the use of intern software engineers. This resulted in substandard outputs that were only addressed when quality assurance procedures were implemented. In addition, the central database suffered a massive virus attack when it was initially interconnected with the existing server. This destroyed the software infrastructure of the central database and infected some remote databases. It took over one month to strip the central server, reformat it and reconstruct the database. Recommendation to counter this is to establish a mirror server on the Internet in order to avoid loss of data.

Shortfalls in the traceability system

At the time of writing, a number of limitations continued to plague the system. These included:

Data: Limited breadth and depth of information were captured specifically neglecting information at the production level; Besides, critical information for purpose of export certification remained with the VSD and was not readily available to third parties;

Organization / Culture: The VSD maintained a compliance driven mindset limiting full deployment of the system. Then pastoral productions straddling national boundaries implied that the system required a regional approach to implementation; and some of the veterinary procedures and processes were not standardized within the districts.

It is with realisation that addressing such gaps would have to be sorted in the long-term, the study focused on implementing the study straddling two provinces rather than national boundaries. This was because the study lacked to operate beyond national boundaries.

Market infrastructure

A number of infrastructural deficiencies were noted during implementation of the system. This included lack of market infrastructure such as stock routes, holding grounds and quarantine facilities. This necessitated the encroachment into and use of private property such as Chakama ranch. In addition, there was poor capacity to transfer data through the GPRS modem because of the presence of large areas of ‘dead zones’ that had limited or no internet connectivity. Figure 5 shows part of the route into the coastal ranches. The portion passing the Tsavo National Park was marked in red.

Figure 5. Livestock trekking route Garissa to coastal ranches

Discussions of field implementation

Two aspects are covered in this discussion, first the technical feasibility on the use of RFID as identifiers under pastoral production systems; second, the overall feasibility of electronic LITS in meeting the three objectives of the VSD.

The use of RFID tags (ear button tags or rumen boluses) were both technically applicable for automatic individual identification and traceability in a pastoral environment. This was particularly so when supported by robust SOPs. This finding is consistent with the finding of other studies that recommends use of electronic traceability systems and makes the shift towards RFID livestock identification inevitable (Atterton and Ward 2007, Carné 2009b, Peets et al 2009). Of the two types of tags, the rumen boluses by the were more preferred because they could be recycled up to ten times and were also tamperproof, thus cheaper in the long-term. Comparatively, ear button tags deteriorated rapidly and a number lost after two months. This was attributed to ear infections, ear tearing and the locking system expanding. Exposure to the intense sun in the ASAL area also led to plastic deformation or breakage.

LITS was able to integrate electronic data capture and reporting technologies into existing disease control programs, automated data capture technology and integrating handheld computers/ readers to replace paper-based forms. Animal health officials were therefore able to electronically record and submit essential data to the central data base. This resulted in increased the volume and quality of data collected, minimized data errors, and increased the speed of data entry into a central database (Gasparin et al 2007).

The experience of this study showed that retrospectively "fixing" data problems was considerably more expensive when compared to the process of ensuring good quality data is obtained in the first place. In order to secure sound data, the Veterinary Department personnel were exclusively tasked with collection and entry of livestock data. However, it was recognised that their skills in computer data entry and manipulation needed further upgrading through training.

Among the benefits observed were that electronic LITS ascribe specific responsibilities to individual veterinary personnel. By focusing on the individual practitioner, the system was able to inject greater diligence in administering procedures and inspections since any errors could be traced to an individual. This resulted in minimal errors and therefore a more stringent application of certification procedures.

The LITS was also able to meet rigorous and defined performance standards such as determining the location(s) where a specific animal was registered, its cohort (same herd) as well as those animals it has been in contact with from the central database. It is notable that such a level of performance is not achievable without electronic recording and submission of data enabled by RFID. By adopting electronic data submission, the system avoided inefficiencies associated with paper-based systems.

The LITS was able to facilitate near real time transfer of data. This improved efficiency, reduced errors and saved time and/or labour along the livestock marketing chain. In addition, the system was able to identify a single CBPP infected case from the total of 1943 animals thus demonstrating a high level of sensitivity and reliability during sero-surveillance. Despite the high cost of start-up, electronic identifier systems have been more reliable when compared to visual systems. They cannot be lost, falsified or inter-changed thus making it difficult to lose information (Carné et al 2009 a,b). For this purpose a cost benefit analysis can be a good basis for decision prior to wide-scale implementation.

Conclusions

- The study noted that while the implementation of electronic traceability systems was a costly undertaking, it was technically feasible in pastoralist's production systems. However, the full participation of stakeholders is essential for successful implementation. It is recommended that rumen boluses should be used as identifiers for a mandatory but public sector driven livestock identification. A high degree of private sector participation would ensure sustainability when the system is adopted as part of the regular activities of the VSD.

Acknowledgement

We wish to acknowledge and thank the European Union (Somalia Unit) for funding the traceability field trial. The contributions of Terra Nuova, the VSD and Virtual City to this study are appreciated. This work was done under the framework of the Improvement and Diversification of Somali Livestock Trade and Marketing Project implemented by Terra Nuova.

References

Atterton J and Ward N 2007 Diversification and Innovation in Traditional Land-Based Industries, in Mahroum S, Atterton J, Ward N, Williams A, Naylor R, Hindle R and Rowe F Rural Innovation, National Endowment for Science Technology and the Arts (NESTA): London.

Caja G, Conill C, Nehring R and Ribo O 1999 Development of a ceramic bolus for the permanent electronic identification of sheep, goat and cattle. Computer Electronics in Agriculture 24:45-63.

Cantor AB 2003 SAS Survival Analysis Techniques for Medical Research. 2^{nd} ed. SAS Institute Inc., Cary, NC.

Carné S, Caja G, Ghirardi J J and Salama A A K 2009a Long-term performance of visual and electronic identification devices in dairy goats. Journal of Dairy Science 92:1500–1511 http://download.journals.elsevierhealth.com/pdfs/journals/0022-0302/PIIS0022030209704618.pdf

Carné S, Gipson T A, Rovai M, Merkel RC and Caja G 2009b w. Journal of Animal Science 87:2419-2427 http://jas.fass.org/cgi/reprint/87/7/2419

Gasparin C P, Peets S, Blackburn D W K and Godwin R J 2007 Stakeholder requirements for traceability systems. In J V Stafford (Editor). Proceedings of the 6^{th} European conference on precision agriculture (pp 793-799). The Netherlands: Wageningen Academic Publishers.

Ghirardi J J G, Caja D, Casellas G J and Hernandez-Jover M 2006 Evaluation of the retention of electronic identification boluses in the forestomachs of cattle. Journal of Animal Science 84:2260–2268 http://jas.fass.org/cgi/reprint/84/8/2260.pdf

ICAR 2004 Development of Animal Identification and Recording Systems for Developing Countries ICAR Technical Series no. 9. Proceedings of the ICAR/FAO Seminar held in Sousse, Tunisia, 29 May 2004. Editors: R Pauw, S Mack and J Maki-Hokkonen 186 Pages. http://www.icar.org/Documents/technical_series/tec_series_09_sousse.pdf

ICAR 2009 International agreement on recording practices. Guidelines approved by the general assembly in Niagara Falls. 517 Pages. http://www.icar.org/Documents/Rules%20and%20regulations/Guidelines/Guidelines_2009.pdf

Kleinbaum D G and Klein M 2005 Survival Analysis: A Self-Learning Text (Statistics for Biology and Health). 2nd edition. Springer, New York, NY.

Peets S, Gasparin C P, Blackburn D W K and Godwin R J 2009 RFID tags for identification and verifying agrochemicals in food traceability systems. Precision Agriculture 10:382-394.

Pinna, W, Sedda, P, Moniell, G and Ribó O 2006 Electronic identification of Sarda goats under extensive conditions in the island of Sardinia. Small Ruminant Research 66: 286–290

Ribó, O, Poucet, A, Meloni, U, Korn, C, and Cuypus, M 1999 Idea project-guide procedures (v5.3), Safeguards and Verification Techniques Unit, Institute for Systems Informatics and safety, Joint research Centre, Ispra, 78pp, (Technical Note No. 1.99.159).

Schwägele F 2005 Traceability from a European perspective. Meat Science, 71:164-173.

Shanahan C, Kernan B, Ayalew G, McDonnell K, Butler F and Ward S 2009 A framework for beef traceability from farm to slaughter using global standards: An Irish perspective. Computer and Electronics in Agriculture 66:62-69.

Smith G C, Tatum J D, Belk K E, Scanga J A, Grandin T and Sofos J N 2005 Traceability from a US perspective. Meat Science 71:174–193.

Tajima M 2007 Strategic value of RFID in supply chain management. Journal of Purchasing Supply and Management 13:261-273.

Received 24 February 2010; Accepted 11 May 2010; Published 1 October 2010