e-Bangi Faculty of Social Sciences and Humanities Universiti Kebangsaan Malaysia
Journal of Social Sciences and Humanities
Special Issue: Vol. 19. No.3 (2022). 108-122. ISSN: 1823-884x
Theme: Human, Nature and Society

PROPOSING INTERNET OF THINGS INTEGRATION INTO DEOXYRIBONUCLEIC ACID TECHNOLOGY FOR COMBATING STOCK THEFT IN KWAZULU-NATAL PROVINCE OF SOUTH AFRICA

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ABSTRACT

The ever-increasing stock theft in the selected areas of KwaZulu-Natal (KZN) Province seems to be uncontrollable. Heavily reliance on the use of conventional methods, such as brand-marking and tattooing and legislative frameworks, like the Stock Theft Act (No. 57 of 1959) and Animal Identification Act (No. 6 of 2002) in attempting to quell this crime currently proved ineffective. In responding to this elusive scourge, the objective of this study was to propose Internet of Things (IoT) integration into Deoxyribonucleic Acid (DNA) technology for combating stock theft in the selected areas of KZN Province. This qualitative study was guided by the descriptive and exploratory research designs, with approximately 49 participants purposively selected from various Anti-Stock theft stakeholders. The Focus Group Discussions (FGDs) and Key Informant Interview (KIIs) were adopted for data collections. The inductive Thematic Content Analysis (TCA) was also employed for data analysis. This study *established* that IoT allows livestock farmers to improve their livestock management through activity and movement-monitoring. Thus, the sought integration with DNA technology can adequately aid to evidence gathering relating and livestock identification by offering DNA characteristics. It is *recommended* that all Anti-Stock theft stakeholders should highly consider undergoing educational courses and other related trainings based on the effective use of IoT and DNA technology to physical match livestock ear notches and brands, as well as provide specific descriptions and verifications of their near real-time visibility in varying periods respectively.

Keywords: Combating, Deoxyribonucleic Acid technology, Internet of Things, Stock theft, South Africa

INTRODUCTION

The problem of stock theft on farms appears to be widespread, and often involves serious financial and personal losses to farmers. The isolation of many rural areas, the ease of access to most properties through improved road systems and modern vehicles, the increasing value of chemicals, machinery and equipment on farms, and the portable nature of livestock and equipment, mean that farms are an inviting target for thieves, vandals and other criminals. Memon, Kumar, Memon, Chowdhry, Aamir and Kumar (2016:1) confirm that stock theft has been a main problem in the agricultural sector in many countries around the world and threatens both commercial and the emerging farming sectors. This scourge is regarded as an emotional topic for farmers, but the full impact has not yet been realised. Most farmers seems to be apathetic towards the problem and only react when someone steals from them. Most of the operations and patrols focusses on the so-called runners who are responsible for stealing the stock.

Farmers and the South African Police Service (SAPS) are using an enormous amount of energy, time, and resources to combat stock theft, but they are fighting a losing battle at this point. The responsible stakeholders are urged to change latest strategies to combat the wave of stock theft and this can only be done by looking at the extent, modus operandi of the syndicates and outlets of stolen stock. There are more than 131 000 cases of stolen stock each year. The Free State alone has about 4 000 stock theft cases reported yearly. A significant amount of stock thefts are not reported as farmers feel that nothing will be done in any case which means that thousands more cases need to be added to these numbers, Harvest South Africa (2021).

The Statistics South Africa [Stats SA] (2021) (in Democratic Alliance – DA, 2021) reveals that non-reporting of stock theft comes down to about 70.7% of cases. It is estimated that the value of livestock stolen during 2019/2020 to be around R1 179 458 600. On average there are about 182 Cattle, 282 Sheep and 138 Goats being stolen every day in South Africa (Harvest South Africa, 2021). Unchecked stock theft is fast becoming one of the gravest challenges to South African farmers, as they wake each day expecting to find hundreds of their Cattle or Sheep or Goats have been stolen. This on top of murderous farm attacks, the drought, and the constant threat of expropriation of their farms with zero compensation has our farmers at breaking point, for example, between July and September 2020, there were 7 339 cases of stock theft countrywide, which saw over 26 300 Sheep and 14 000 Cattle stolen.
The Harvest South Africa South Africa (2021) shares that it should also be noted that stock theft is still regarded as an African crime that forms part of rural criminality. The extent of stock theft is simply too great to just be sold on the informal market. Stolen stock are rebranded and then added once again into the production chain where they are sold at auctions to farmers, livestock speculators and abattoirs. Stock theft, as such, is then a specialised, organised crime. Furthermore, the impact of stock theft is just as big, if not bigger, than that of robbery of Cash-In-Transit (CIT) vehicles and therefore must be taken seriously. To combat stock theft effectively alternative approaches and strategies needs to be considered and a stock thieve can be a neighbour, local livestock speculator or auctioneer. Do not be the one to buy stolen items on the street corner. Thus, the local livestock farmers must take responsibility for branding their stock and having the correct documentation filled out to avoid the possibility of a criminal record. Auctioneers and speculators can no longer shrug and say that they did not know. It is high time that this industry is cleaned up (Harvest South Africa South Africa, 2021).

For a recourse, Kempen (2015:10) highlights that the DNA technology can be positively used to link stock thieves to stock theft scenes, with the aim of accuracy identifications using biological evidence. This technology can also clear potential suspected stock thieves and it can also exonerate them from mistakenly accused or convicted of stock theft. This technology is increasingly playing a vital role in ensuring the indicated accuracy and fairness in the South African Criminal Justice System (CJS). In addition, the researchers presents that the applications of DNA technology and IoT should be regarded as pivotal forensic instruments to effectively combat this crime and should be also viewed as one of the essential components of the local CJS, as these technologies can offer accomplishments to the following characteristics; ‘DNA evidence typing and samples usage, ownership determinants (I.e. Kingship identifications), paternity testing procedures, management and monitoring of

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livestock movements, minimising of livestock potential danger, tracking of straying livestock, providing better improvements of production efficiency and reduction of costs.

The DNA-based technologies are largely used for the determination of identity, ownership, percentage, traceability and the species origin of animal products such as tissue, blood and skin. Apart from identical twins or clones, no two animals are genetically the same, National Stock Theft Prevention Forum [NSTPF] (2016:34). Subsequently, this means that the DNA of an animal is a fingerprints or unique identification. Only small quantities of DNA technology is needed to confirm the fingerprint of livestock. Nevertheless, the DNA technology can help to combat stock theft through the applications of the following process: "Hair samples (I.e. A source of DNA) are collected from individual animals and stored in the laboratory as reference samples. When animals are injured or have sloughed at a crime scene, or a piece of meat from a stolen animal is found in possession of a suspect, a tissue sample is taken and compared in the laboratory to the reference sample, NSTPF (2016:34).

Moreover, if the DNA fingerprint of the reference samples agrees with a sample from the crime scene, the suspect can be connected to the crime scene or the crime itself, and evidence can be used to put the offender behind bars. Even if there is no reference sample available, conviction is still possible if DNA from the blood, bloodstains , meat or other tissues found at the crime scene compares with blood found on the suspect's clothes, tools that were used, or meat found in his possession," NSTPF (2016:35). Therefore, the success of the forensic DNA services is dependent on all parties involved correctly collecting samples at a crime scene, processing and analysing them in the laboratory, and reporting the findings. To ensure that each part of the process is handled correctly, the Animal Research Council (ARC) continuously provides training to the SAPS staff. The training focuses on aspects such as DNA sampling, preservation, documentation, and dispatching of samples to the laboratory (NSTPF, 2016:35).

On the other hand, the IoT devices, especially in the form of wearables, have long been used to track human activity. Now, they are used to monitor livestock, Cattle for example. The sensors and softwares are used to collect data for livestock farmers. This is done to monitor their locations and prevent potential theft of livestock; the adopted technologies can pinpoint where livestock roam around or graze (TechRepublic, 2022:1). A study by Wamuyu (2017:1) proposes a framework for remote identification and tracking of livestock movement based on Wireless Sensor Networks (WSN), mobile communication, and Unmanned Aerial Vehicles (UAVs). This technology can be implemented for tracking livestock movement at the [Rural] village level and extended to harsh terrain when recovering stolen animals in case of livestock from possible theft.

This system works by identifying and tracking the desired animal location and sending periodic location data at regular intervals to a database as well as availing the specific animal's current location on demand through the Internet and text messages. The proposed 'Cattle Tracking and Recovery System (CTRS) consisted of a rumen sensor module, a WSN control unit, a Worldwide Interoperability for Microwave Access (WiMAX) gateway, WiMAX base stations and a data centre. Availing timely information about the location of the stolen animals could facilitate quick recovery of the animals while ensuring the safety of the security personnel involved in the recovery process. Speedy recovery of stolen animals also defeats the purpose of stock theft, as the rustlers do not have the chance to use the animals for their intended purposes, Wamuyu (2017:1).

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Importantly, the researchers were interested in proposing IoT integration into DNA technology for combating stock theft in the selected areas of KZN Province. This was done to offer a much-needed support should be directed at the livestock farmers by the South African government, SAPS management and other relevant stakeholders. As it is envisaged by the researchers that stock thefts have the potential to cause serious negative impacts, and there are high indications of this crime diversifying and extending into new realms. This crime is not only affecting rural emerging livestock farmers, but also the established individuals in the commercial farming sector as well. It is a fact that if it is not successfully controlled, it will not only threaten the sustainability of the South African livestock sector and the competitiveness of this sector. Therefore, this study commands that support is required for the development and adaptation of IoT and DNA technology to combat stock theft in the selected areas of KZN Province. The SAPS, together with the relevant stakeholders as identified by this study and others, should develop and facilitate the integration of available conventional methods of combating stock theft with IoT and DNA technology.

REVIEW OF LITERATURE

Van Eenennaam (2010:66) defines DNA as living organisms that are made up of cells, and located on the inside of each cell is DNA. The DNA is made up of pairs of Four (04) Nucleotides, abbreviated as ‘A’, ‘C’, ‘G’, and ‘T’. The entire genetic make-up, or genome, of an organism is stored in one or more chromosomes located inside each cell. The DNA has two important functions; firstly, it transmits genetic information during reproduction, and secondly, it continually reveals the identity and the rate of assembly of proteins. Proteins are essential to the structure and function of plants and animals. In particular, DNA contains the instructions for making proteins. Differences in the Nucleotide sequence of a gene’s DNA could influence the type or amount of protein that is made, and this could have an effect on the observed performance of an animal. A gene is a distinct sequence of DNA that contains all the instructions for making a protein. It is possible for the DNA sequence that makes up a gene or ‘locus’ to differ between individuals. These alternative DNA sequences or forms of a gene are called “alleles”, and they can result in differences in the amount or type of protein being produced by that gene among different individual animals. This could affect the performance or appearance of animals that carry different alleles, Van Eenennaam (2010:66). Van Eenennaam (2010:66) went on to states that ‘Alleles’ can be recessive, meaning that an animal must inherit the same allele, as well as the same sequence, from both parents before there is an effect on performance or appearance; additive means that an animal inheriting different alleles from each parent has an observed value or phenotype that is an intermediate between animals carrying identical copies of the two alternative alleles; or dominant, meaning that the presence of one allele is sufficient to result in an effect on the trait or attribute of interest. Gender determination is a well-known example of a simple trait where the presence of the dominant ‘Y’ chromosome dictates maleness. The Single Nucleotide Polymorphism (SNP) genetic tests focus on detecting precise, Single Nucleotide base-pair differences among the Three (03)-billion Nucleotide base pairs that make up the bovine genome (Van Eenennaam, 2010:66).

Apart from the use of DNA technology to combat stock theft, the research consulted indicates that notable DNA technologies are often applied by researchers in the academic fields of Animal and Plant Sciences, Environmental Sciences and Agriculture Animal Health

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and Human Ecology, to name a few and in Africa, the IoT plays an increasingly important role in sectors like agriculture and healthcare. Agriculture in Africa is being affected by climate change and water shortages, yet there is a growing population in need of sustainable food security and greater financial inclusion. According to Global System for Mobile Communications (GSM), mobile subscriber penetration in Sub-Saharan Africa in 2020 was 46% and is expected to reach 50% by 2025. More importantly, smartphone adoption was at 48% in 2020 and is expected to reach 64% by 2025. It is common in Africa to have access to a mobile phone but not to water or electricity Consumer News and Business Channel [CNBC] Africa, (2022). The IoT refers to the recent technology that is gaining wide awareness and acceptance in several fields due to its practical relevance in everyday life improvement. This technology is presently [I.e. 2022] found its utility in the agricultural sector [I.e. The prevention, combating and investigation of stock theft included], with IoT, agricultural practices is made modern and easy, it improves operational efficiency, drives productivity, creates new revenue sources and, ultimately, makes sustainability synonymous with profit (Bamigboye & Ademola, 2016:309 & 311).
With the use of the IoT-advanced livestock tracking system, such as the 'Cattle Tracking Collar,' the livestock can be secured and protected from theft, injury, natural disaster and organised crime, the livestock farmers can be able to gain remote visibility on livestock location. For practicality, the Global Positioning System (GPS) Cattle collar sends out a signal every 15 minutes, straight to livestock management dashboard. This means that the livestock location can be remotely monitored at any time, from anywhere. The specific 'GeoFences' can also be set-up to offer notifications nor alerts when livestock moves out of a designated area (Smarter Technologies, 2021:1). The IoT Cattle Collar tracks and monitors the location of every individual in the herd to enables livestock farmers to accomplish the following:

- Prevent livestock theft;
- Track and recover stolen animals;
- Count stock within a matter of minutes;
- Identify individual animals with ease;
- Detect unusual behaviour;
- Save time by accessing location information in the palm of your hand;
- GeoFence to prevent animals from straying out of the designated grazing area; and
- Gain complete visibility of livestock [I.e. Cattle's] location at all times, Smarter Technologies (2021:1).

For illustrations; the 'FindMy' collars communicate with Globalstar satellites to GeoFence livestock, helping to ensure animals graze only in designated areas, and to locate those, which have escaped or are injured, Africa's farming sector, where livestock often roam fence free, has seen huge growth in demand for satellite IoT technology in recent times. Livestock theft is a serious daily problem, and predators pose extra risk. Farmers are embracing satellite technology as they see the value of reliable tracking and geo-fencing. Streamline South Africa developed its IoT-enabled Guardian Animal Tracking Collar based on Globalstar's ST100 IoT chip, and it is growing in popularity. In one deployment, Streamline's collar is tracking 7,500 Cattle on 67,000 hectares in South Africa. This is the home of the world's biggest herd of Pinzgauer Cattle, an Austrian breed praised for its fertility, disease-resistance, and high beef quality (Murphy, 2021).

In the past, in any year, as much as 30 percent of the herd could be written-off with causes ranging from lost stock, theft and fatality from Cliff falls. Due to the vast expanse, challenging topography, and limited GSM coverage, it takes a large amount of resource in the form of personnel, air and land vehicles and fuel to conduct searches for missing animals. As livestov [I.e. Cattle] moves in herd groups following leaders, it is usually sufficient to track only the leader cows. Each Streamline Guardian collar is powered by a solar panel with 500 milliampere-hour (mAh) battery. The Globalstar ST100 board is enclosed in Polyetherimide casing and 40-50mm industrial web belt with embedded steal cable is used for the collar material. The collar is fastened with secure lock bolts with counterweights to keep the module positioned with best line of sight (Murphy, 2021).

Swedberg (2017:1) shares that in Uruguay, the ‘startup Chipsafer’ completed Two (02) pilots of the IoT-based solution to track the activities of beef livestock and prevent stock theft, including Cattle rustling. The system employs long-range (LoRa) and LoRa wide-area network (LoRaWAN) technology from the ‘Semtech’ company, as well as Chipsafer's wireless sensors worn by Cattle. This solution is intended to help ranchers understand livestock [I.e. Cattle] behaviour and detect a problem, such as a Cow being removed from a ranch or falling ill, when they attach Chipsafer’s wireless sensor transmitters to the animals. While the 02 pilots, one carried out in Namibia, the other in Kenya were reported to be complete, similar ongoing pilots are under way in Brazil, Uruguay, Luxembourg, the Netherlands and Australia. According to this company, the system is designed to provide a low-cost solution for tracking animals in ranch environments in which Radio Frequency Identification (RFID) or other wireless sensor devices would not be able to interrogate tags. This technology is referred as the ‘Internet of Cows.’

Moreover, with LoRa technology, Ranchers can track and detect anomalies in Cattle behaviour at any time. Data tracked remotely on wide-open Cattle Ranchers can be collected and shared with a Veterinarian anywhere in the world. The disease can be caught early and if necessary, Cattle can be removed to prevent a spread of infection. Also with LoRa-based sensors, Ranchers are able in real-time to locate their Cattle to better manage the herd and reduce stock theft. Sensors typically cost the Rancher between 10 USD [I.e. R77,90] and 50 USD [I.e. R779,12 – By the time of compiling this study], enabling a Return On Investment (ROI) against disease loss or theft of livestock (Semtech, 2022).

A study conducted by Maroto-Molina, Navarro-García, Príncipe-Aguirre, Gómez-Maqueda, Guerrero-Ginel, Garrido-Varo and Pérez-Marín (2019) reveal that animal location technologies have evolved considerably in the last 60 years. However, nowadays, animal tracking solutions based on GPS are commercially available, negatively, some existing devices have several constraints, mostly related to wireless data transmission and financial cost, which make impractical the monitorisation of all the animals in a herd, among others. These authors developed a low-cost solution to enable the monitorisation of a whole herd. They used an IoT-based system, which requires some animals of the herd being fitted with GPS collars connected to a ‘Sigfox’ network and the rest with low-cost Bluetooth tags. They tested its performance in two commercial farms, raising Sheep and Beef Cattle, through the monitorisation of 50 females in each case. It is recorded that several collar/tag ratios, which define the cost per animal of the solution, have been simulated. The results demonstrated that a low collar/tag ratio enable the monitorisation of a whole Sheep herd.

It was recommended that a larger ratio is needed for Beef Cattle because of their grazing behaviour. Nevertheless, the optimal ratio often depends on the purpose of location data. While, large variability has been observed for the number of hourly and daily messages from collars and tags. The system effectiveness for the monitorisation of all the animals in a herd has been certainly been proved, which is highly commendable. Based on the integration of Low Power Wide Area [LPWA] (Sigfox Labège, France) and low-cost Bluetooth Low Energy (BLE) sensor networks, has been demonstrated to be effective in monitoring the location of each animal in a herd at a much lower cost than existing solutions. The collar/tag ratio, which defines the cost per animal of the solution, should be adapted to each case, mostly depending on the utilities associated to animal location data, Maroto-Molina *et al.* (2019).

Moreover, the study by Memon *et al.* (2016:7) designed an IoT enabled smart animal farm. This is a cost efficient system and is built with a cost of USD300 [About R4 688,61 by the time of compiling this study]. It continuously monitors the physical parameters of an animal farm. It can be controlled manually as well as automatically. This kind of system is suitable for any kind of animal farm with little modifications. A study conducted by (Nkwari, Rimer & Paul, 2014) provide that a Wireless Sensor Node (WSN) can be used to sense the position and speed of a Cow [I.e. Cattle]. The position and the speed of the Cow are collected for analysis. A random walk model was applied to the cow's position in order to determine the probability of the boundary condition where we assume there is an increased probability of a cow on the boundary position being stolen. The Continuous Time Markov Processes (CTMP) is applied to the movement pattern of an individual Cow in order to find the probability that the cow will be at the boundary position.

The value of 2.5 kilometre per hour (km/h) has been found as our threshold to detect any agitation of the animal. The Cow has less probability to be at the boundary position. The predictive model allows us to prevent stock theft in farms especially in South Africa and Africa in general. These authors proposed a framework to prevent stock theft by applying the CTMP to Cattle movement. The integration of the probability density function allows us to find the probability in any region. They applied the CTMP to Cattle in order to obtained random tendencies for a given probability. In practice, this approach enabled them to see the behaviour of the individual cow specifically and for the herd in general. The behaviour was plotted to enable them to obtain an expected value for the threat zone, Nkwari, Rimer and Paul (2014).

Another study shares that tracing stolen livestock [I.e. Cattle] in the 'Lombok Tengah regency of *Nusa Tenggara Barat* (NTB) Province' was carried out by tracing footprints and waiting at certain location points which are considered as the route to be traversed or the final destination of Cattle theft which is called *'Ngendeng,'* this practice is carried out day and night from the time the livestock is declared missing until the livestock is found or the potential to be found is considered lost. The problem that occurs in during the associated activities is that it endangers the safety of life if there is a clash with thieves and a decrease in health for the responsible individuals. Therefore, to replace the community respective roles; an IoT device for image capturing was developed. This device can take a picture if someone passes through the front of the device then it is sent to the Telegram account of the 'District Police and the Community telegram account,' it is also found the most frequently traversed point (I.e. Very potential) to place the IoT-based image capture devices as an effort to reduce the crime of Cattle theft in Lombok Tengah Regency (Imtihan, Bagye, Zaen, Fadli & Ashari, 2020).

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Fourie (2022) highlights that data from the Guardian collars on the Cattle and from the SpotGen3 devices on the ground; patrol is pushed to the Spot My Globalstar platform, which allows for an overview of activity on the farm. For the ground patrol, GeoFences were set in specific farm management areas for Enter, Exit or both. The client is sent messages indicating the time of entry and exit at specific Geofence locations throughout the day. For the Guardian animal collar, GeoFences were set around the Cattle containment area as well as on borders to high-risk areas such as cliffs. When animals breach the containment GeoFence or the high-risk area border, the client will receive a message alert. The nearest ground patrol resource to the alert event can be located on the platform and contacted to respond. These GeoFences and alerts are easily set up and managed remotely in the Spot My Globalstar platform, allowing for a more efficient livestock [I.e. Cattle] management and farm personnel programme, which greatly reduces costs related to expensive searches and management.

The client has already noted a significant increase in ground personnel productivity with the 'check-in' clocking system via the Gen 3 devices and has reduced Cattle search related costs by over 30%. The Streamline Guardian Animal Tracking Collar has many applications on the African continent, which extend beyond the Cattle industry to other livestock and wildlife sectors. With vast areas, often with poor infrastructure and connectivity, this collar can be a key element of remote animal management in Africa, Fourie (2022).

Today's [I.e. 2022] agriculture industry is data-cantered, precise, and smarter than ever. The internet of things allows farmers, ranchers and beekeepers to stay connected to their fields and stock like never before. The next generation of smart agriculture solutions, powered by Sigfox's dedicated IoT network, removes the barriers posed by earlier generations of connected devices. The newest solutions are affordable, user-friendly, and provide uninterrupted connectivity even in the most remote locations, Sigfox.com (2022).
Equally, livestock management is a complex, around the-clock job, but no rancher can be everywhere at once-until now. Smart livestock collars provides a virtually fence and track livestock herd via GPS, even when you are far from the ranch. Gather real-time information about location, speed, body temperature and stress levels of livestock. Reduce inefficiencies, decrease operating costs and improve the health and safety of Cattle, Horses, Sheep and Goats. Moreover, traditional gate alarms rely on cellular networks, making them useless in remote settings. Smart alarms on the Sigfox network function even in the farthest reaches of a farm or ranch. Secure your gates and deter stock thieves with a rugged, tamper-proof device that is intelligent enough to differentiate between human and animal movement. Rest easy knowing you can remotely monitor all of your gates from a single dashboard (Sigfox.com, 2022).

Geldenhuys (2011:37) reveals that from the year 2010 onwards, scientists started to identify regions of DNA that influence production traits. They have used the techniques of molecular biology and quantitative genetics to find differences in the DNA sequence in these regions. Tests have been developed to identify these subtle sequence differences and so identify whether an animal is carrying a segment of DNA that is positively or negatively associated with the trait of interest. These different forms of a genetic marker are known as DNA marker alleles. There are several types of genetic markers. Microsatellites are stretches of DNA that consist of tandem repeats of a simple sequence of Nucleotides (I.e. For example: 'AC' repeated 15 times in succession). The tandem repeats tend to vary in number such that it is unlikely that two individuals will have the same number of repeats. To date, the molecular

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markers used to determine parentage have primarily utilised microsatellite markers. Another type of genetic marker is referred to as a 'SNP,' also referred to as 'snip'.

RESEARCH METHODOLOGY

The study was carried out with questions that were tailored along the descriptive and exploratory research designs. The participants were purposively drawn from the selected areas of KZN Province, based on the rationale that the researchers were aware of certain categories of participants that could provide more detailed information on the phenomenon under examination. Such selections were also based on the participants' years of experience in relation to the subject matter and being relevant stakeholders in the combating and prevention of stock theft in that province. All participants were Africans and Whites, fluent in both *IsiZulu* and English.

About 49 participants were sampled in this study, and the adopted procedure comprised of relevant stakeholders who participated in a series of FGDs and KIIs, as follows: Two (02) Department of Agriculture, Forestry and Fisheries (DAFF) staff [Assistant Directors: Animal Technicians and Animal Production officials] (KIIs); One (01) SAPS Stock Theft Unit (SAPS STU) Provincial Co-ordinator (KII); 38 KZN SAPS STUs members (I.e. 14 by means of KIIs; and 24 forming part of the FGDs); Eight (08) livestock farmers (FGDs); Three (03) Community Police Forum (CPF) members/chairpersons (KIIs); and five Anti-Stock Theft Association managers (KIIs).

During the record-taking process, the researchers took notes, with a view to writing a more detailed and complete report afterwards. A voice recorder was also used for FGDs and KIIs, with a view of transcribing the information gathered at a later stage. The researchers then organised the obtained data by categorising it based on themes, concepts or similar features. The researchers further ensured that the elicited data answered the objective guiding the research study. The researchers read the data several times to grasp the selected participants' perceptions on this subject. This was done by making cryptic written notes of what the participants were saying during the FGDs and KIIs to elicit themes. The actual words used by the participants were written down verbatim (word-for-word) (Manganyi, Maluleke and Shandu (2018:99 & 100) and Matlala, 2012: 113 & 114).

FINDING AND DISCUSSION

Importantly, the empirical findings of this study stemmed from the following question, as posed to all the selected participants: *'How can IoT and DNA technology be integrated to effectively to combat stock theft in your area?* Therefore, the participants' responses are presented herewith in verbatim:

> *"Quick feedback from ARC-Irene should be encouraged to accelerate the prosecution process, for example; in cases where a calf is stolen and over-branded whereas both parents are still alive belonging to the complaint, DNA technology can be positively used to prove ownership. In other cases DNA technology can be used to prove ownership of a tattoo marked calf on the ear or gums"* **(KII-03:07:07).**

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When asked about the factors impeding the effectiveness of using IoT and DNA technology to combat stock theft in their selected areas, they mentioned the following factors:

> *"While noting the importance of IoT and DNA technology in combating stock theft, they are issues that come upfront, like for instance, we had an issue the other day when one of our members received DNA results samples back from ARC-Irene and I really do not what happen there but the case numbers did not correspond with the cases numbers as sent to Irene when it come back, it was completely difference and the results received did not make sense. So we had to send back these results and make a query about it and then after that they eventual send back the results with correct case numbers but incidences of this kind do not happen a lot"* **(FGDs-04:16:8).**

> *"The current system (IoT and DNA technology) does not comply with the systems of the traditional leaders; they can oppose anything with everything (might) that is the reason why we cannot have these improvements. There are more challenges to be precise"* **(KII-01:01:01).**

> *"Quite few of our cases has been stricken off the roll because of the fact that we wait longer time for the financial authority process to be finalised and still have to send the DNA evidence away and wait for another three (3) to four (4) weeks for the feedback from the laboratory (for the results to come back0. In that period of time the court refuses to remind the dockets two (2) and three (3) times and just strike off the roll and by that time you receive positive results then you have another problem you struggle your backside to go and find the accused as he / she is given bail or out and running away and struggle to locate that accused, that is also a big challenge that we have"* **(FGDs-04:16:6).**

> *"A friend of mine told me that the Donkeys walking next to the road belong to no one if it is hit by a car but if it gets stolen the owners will come forward, they will come after you with all they have, and you will quickly learn who the owner is. It is a big battle over the world, people think stock theft is only a South African problem, it is definitely not only our problem, it is a world over problem"* **(KII-01:01:01).**

> *"Some of our local courts do not consider stock theft as priority crime, even when they give convictions they normally give three (3) months or suspend the sentence. It is very important to understand the value of livestock for African people as it is their back, their money"* **(FGDs-04:16:6).**

> *"We have got another case where I took human DNA using buccal swab evidence method – taken from the suspect's mouth and have Touch-DNA from the recovered firearm to send to Cape Town laboratory. It is five (5) / six (6) months in and we were told that it can take-up to a year for them to send the results back. Touch-DNA can directly connect the suspects to the crime scene if found and proven positive, it is like a fingerprints. We sent the samples and now we do not know which suspect(s) handled the firearm. Only if we can have a method of making this processes quicker, not a method of 'hurry-up-and-wait'. It should be noted that human DNA evidence results take very long to come back, sometimes it can take-up to six (6) – seven (7) months"* **(FGDs-04:16:5).**

> *"There are many things to do, including the following among others:*

- *Awareness campaigns to Communities and livestock owners by the Kwa Zulu-Natal, Department of Community Safety and Liaison (KZN DCSL);*

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- *Marking of unmarked livestock by Department of Rural Development and Land Reform (DRDLR); and*
- *Utilisation of Livestock Association meetings, Stock Theft Information Centres (STICs) to educate Communities on:*
  - *Relevant legislation;*
  - *Marking of livestock;*
  - *Hints to safeguard livestock;*
  - *Hints of prevention of stock theft; and*
  - *Utilisation of Livestock Identification Catalogue [LIDCAT] methodology by livestock owners to build a data base at the ARC-Irene"* **(KII-06-02-01).**

> *"So what we have done from National Stock Theft Prevention Forum (NSTPF) perspective, we have applied to use the Central Analytical Facilities (CAF) of University of Stellenbosch, Cape Town as well but the current government works with tenders, they presently (2016) got this tender with the ARC-Irene. They just bluntly refused to use any other laboratory. Another thing that makes it little bit difficult is that people do not want to pursue it because it is a long process, it does not shorten the process, it does not speed it up, it only prolong the process, that plays a huge role as well, considerably; the application of IoT, as an aid to the functioning of DNA technology should be urgently looked at"* **(KII-01:01:01).**

> *"I do think that, although I am a very big supporter of tattooing and branding, we can use other means of animal identification and IoT and DNA technology are some of them (Part one) but the world is improving and changing. There are things like Microchips, Bolus (Botswana and Namibia systems). In essence there are so many other means of animal identification. In all honesty; I think one of our biggest problems in South African Constitution (The Constitution of Republic of South Africa, 1996 is that the status given to the traditional leaders, they have such a big impact on the current CJS. If they do not sign off on anything then that new law just do not get approved, like the Pounds Act (proposed National Animal Pounds Bill – Notice 398 of 2013) we have at the moment. We have struggled for the past three (03) years to get it signed off. It gets stacked at the traditional leaders' zone, they do not want to sign off on anything that is seen as a barrier to them"* **(KII-01:01:01).**

There are issues that emerged during the fieldwork period and that the researchers thought were important for this study. The use of IoT and DNA technology for combating stock theft seems to be a new concept to the livestock farmers residing in the selected areas of KZN Province. This can be also said about CPFs leaders and DAFF personals. Another development is that local SAPS STU officials and Anti-stock theft associations are knowledgeable about the practice under investigation. However, the interviewed participants noted that they faced various difficulties associated with stock theft. The data was collected around the presented themes in the following section. However, there was an indication that an improvement had to be made with regard to the current stock theft combating strategies within the selected areas of KZN Province, in reference to the application of IoT and DNA technology. The study acknowledges some areas where the stakeholders in KZN Province did well in combating stock theft. It was also noted that the primary analysis of study data shows that there is still more to be done to combat stock theft effectively, as a decline in willingness of relevant stakeholders to prevent, combat, investigate, as well as preserve and protect were witnessed.

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THE IDENTIFIED STUDY THEMES AND CHALLENGES

The identified themes and challenges of this study were based on proposing IoT integration into DNA technology for combating stock theft in the selected areas of KZN Province. The following emerged from the conducted analysis:

Inadequate Knowledge and Application of The Use of Deoxyribonucleic Acid Technology and Internet of Things

In stock theft cases where there is no *Prima Facie* evidence before the SAPS STUs members to initiate investigation or carry out an arrest, DNA technology can be positively used to link the potential suspects with the crime in question, whereas, the IoT can efficiently help in securing livestock, based on monitoring their locations, movements, combat and prevent potential stock theft. In light of this finding, these technologies are widely used internationally to solve stock theft cases, with limited usage noticed across South African communities. The stock theft in the selected areas of KZN Province was reported problematic by the time of conducting this study. At the same time, it were acknowledged that there are no plans to establish a Stock Theft Forensic Laboratory (STFL) in the province for the support of DNA technology analysis or to introduce the IoT to efficiently respond to this crime. The participants also stated that it is difficult to deal with the high prevalence of stock theft in the province, while highly ignoring the Two (02) cited applications.

Delay in Obtaining Deoxyribonucleic Acid Samples' Feedback from The Responsible Laboratories and Limited Applications of Internet of Things

During the fieldwork, the livestock farmers indicated a need for the establishments of STFL in the selected areas of KZN Province to avoid the long distances they have to travel to submit the DNA samples in Cape Town, Port Elizabeth and Pretoria. They did not shy away from the fact that KZN Province should be prioritised in this regard. On the positive side, the University of Pretoria and other private companies were acknowledged for been quick in providing the required feedback to the affected parties. However, limited applications of IoT in combating stock theft was also noted by the participants, this require urgent attention.

CONCLUSIONS AND RECOMMENDATIONS

Therefore, this study *concludes* that the members of the selected areas of KZN Province must undergo Stock Theft Learning Programmes (STLP), with the use of the IoT and DNA technology forming part of the modules to be offered. The National Commissioner of the police, in conjunction with the Provincial Commissioner, Stock Theft Provincial Coordinator and SAPS STUs Commanders, should ensure that this occurs regularly. To this end, STLP should be continually staged for the SAPS STUs members in the selected areas of KZN Province to provide an overview of various aspects associated with the fundamentals of the IoT and DNA technology use in combating stock theft. Importantly, with the increasing population, urban cities are expanding and merging nearby town / villages to the City. Therefore, the future of 'Smart City' is dependent upon strong partnership with urban and rural community. The IoT-based technologies refers to a significant boost to the country ecosystem as it can used to combat stock theft. This application can best manage livestock smartly. They can also accurately monitor livestock behaviour and detect livestock [Current] status in terms of health, physiological and risk status.

This study confirmed that this application consists of unlimited capabilities in terms of communication, cloud system, hardware and user-friendly applications. It is also established that stock theft is causes many problems to KZN Province livestock farmers and it is growing rapidly. The existing conventional solutions seem to be ineffective to defeat this flail. The IoT remains one of the lasting solutions, based on accommodating specific rural demographics where livestock are located. The applications of the IoT and DNA technology are highly commendable; the former is coupled with the deployment of LoRa and LoRaWAN technology, with the notion that this application is referred as a new Low Power Wide Area Networks (LPWAN) that offer low cost, low power, and long-range communications advantages.

For recommendations, it was clear that knowledge of the application of DNA technology in combating stock theft was limited from the participants' perspectives. The researchers recommends that more SAPS STU members be trained specifically in the use DNA of technology. It would be best if each SAPS STU in the selected areas of KZN Province could have designated DNA technology experts working along with the respective forensic laboratories across the country. This will assist the SAPS STUs tremendously with their investigation of stock theft, for example in instances when livestock is stolen, illegally relocated or even slaughtered, by being able to use biological samples to link a potential suspect to the crime in question, or to exonerate an innocent person.

It is common knowledge that the IoT and DNA technology has proved to be a solution to the stock theft epidemic by providing rapid means of identification, therefore DNA technology may as well be used as a confirmatory forensic tool in animal identification. The value of these applications are gaining momentum daily as an effective tool to be used in most forms of combating, investigations and prevention, irrespective of either criminal or civil nature.

This study contended that the IoT can presents what is termed 'a whole livestock management system' using predictive theft algorithm to combat stock theft. This application is cost effective for the rural livestock farmers. The adoption of GPS livestock tracking devices by interested parties also foreign to the participants. This also suggests that the benefits, applications and cost implications of using GPS as a livestock tracking device was unknown to the participants, however, they cited that they can become users and likely adopt available new technologies. It was clear that there should be a greater focus on the use and proper applications of DNA technology and IoT in combating stock theft in the KZN Province.

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Journal of Social Sciences and Humanities
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