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Citizen science for development: Potential role of mobile phones in information sharing on ticks and tick-borne diseases in Laikipia, Kenya



Richard Chepkwony^{a,b,c,*}, Severine van Bommel^c, Frank van Langevelde^{b,d}

^a Kenya Wildlife Service, P.O. BOX 40241-00100, Nairobi, Kenya

^b Wageningen University, Resource Ecology Group, P.O. Box 47, 6700 AA Wageningen, The Netherlands

^c Wageningen University, Strategic Communication Group, P.O. Box 8130, 6700 EW Wageningen, The Netherlands

^d School of Life Sciences, Westville Campus, University of KwaZulu-Natal, Durban 4000, South Africa

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ABSTRACT

Ticks and tick-borne diseases (TTBDs) constitute a lethal and widespread problem in many tropical areas, with major ramifications for livestock production, wildlife management, and human health and livelihoods. Despite various control strategies applied, TTBDs remain a complex problem, and integrated approaches must be developed to control them effectively. To address this problem, Wageningen University and Research established an interdisciplinary project in 2015 – Environmental Virtual Observatories for Connective Actions (EVOCA) – that focuses, among other things, on mobile phone-based information sharing platforms for TTBDs in Kenya. This study in Laikipia, a semi-arid savanna area of Kenya, is designed to (i) identify issues that complicate effective TTBD control, (ii) explore whether and how local people use mobile phones to address problems, including TTBDs, and (iii) reflect on what citizen science can contribute to the development of mobile phone-based platforms for TTBDs. The study, conducted between November 2016 and August 2017, adopted a mixed-methods approach comprising 21 interviews, field observations, document reviews, and a workshop. Results suggest that the TTBD problem is compounded by a combination of local issues. Insecurity, human–wildlife conflicts, and occurrences of notifiable zoonotic diseases are among the most pressing issues that affect people and influence the kind of information that they share using mobile phones. The motivation to share information on insecurity and human–wildlife conflicts stems from the urgent need for people to collaborate and facilitate prompt action by the security agencies and expectations of compensation from the government for wildlife damages, respectively. Mobile phone adoption rate in Laikipia is ~70%, suggesting that mobile phones (simple and smart) are widely used for various socioeconomic activities: to communicate with family members and friends and to access information on pressing issues, forming issue-based networks of communication. The widespread use of mobile phones for economic activities such as businesses and banking services have empowered people economically, improving their livelihoods, whereas those without access are probably excluded (disconnected). This study suggests that, despite the widespread adoption of mobile phones, sharing information on TTBDs does not seem to be a major priority for Laikipia residents, as other issues such as insecurity or human–wildlife conflicts take precedence. The design of mobile phone platforms and citizen science for TTBDs should consider such confounding factors to connect with the issues affecting local people.

1. Introduction

Ticks and tick-borne diseases constitute one of the most lethal and widespread problems in many tropical areas, with major ramifications for livestock production, wildlife conservation, and human health (Minjauw and McLeod, 2003; De Castro et al., 1997; Gachohi et al., 2012; Bengis et al., 2002). TTBDs such as East Coast fever (ECF), Bovine babesiosis and Anaplasmosis, among others, constitute 60–80% of the

pathogenic infections causing severe mortalities in humans, wildlife and domestic animals (Cleaveland et al., 2001; Jongejan and Uilenberg, 2004; Estrada-Peña and Salman, 2013). TTBDs may also reduce milk and beef production by 40–50% or lower the quality of skin for commercial purposes (Norval et al., 1988; Jonsson et al., 1998). In areas where wildlife and domestic co-occur, the spread of TTBDs is aggravated due to increased mobility and spread of ticks, increasing the potential risks of disease transmission (Keesing et al., 2013; Gachohi

* Correspondent author at: Kenya Wildlife Service, P.O. BOX 40241-00100, Nairobi, Kenya.

E-mail address: richard.chepkwony@wur.nl (R. Chepkwony).

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et al., 2012). When wildlife is perceived to be involved in the process of disease transmission such as TTBDs, human–wildlife conflicts often result to the detriment of conservation efforts (Benka, 2012). Human–wildlife conflict refers to the negative consequences of the interfaces between people and wildlife, often characterised by human deaths, injuries, crop and property destruction (Okello and D’amour, 2008; Kiringe et al., 2007), and transmission of diseases (Benka, 2012). If uncontrolled, TTBDs therefore remain a threat to human health, food security, and cultural wellbeing, and they negatively affect relationships between farmers and conservationists.

In the eastern and southern Africa region, some widely applied TTBDs control strategies include the use of chemical acaricides (Minjauw and McLeod, 2003; Mugambi et al., 2012), burning of vegetation to reduce tick loads (Goodenough et al., 2017; Trollope, 2011), and keeping livestock thought to be resistant to tick attack, such as Boran cattle (Gachohi et al., 2012). However, cases of tick resistance to chemical acaricides have been reported (Mugambi et al., 2012). Despite all these control strategies applied in the region, TTBDs continue to be a major problem, and integrated approaches must be developed to control them effectively (Gachohi et al., 2012; Mugambi et al., 2012). To address this problem, Wageningen University and Research established an interdisciplinary project in 2015 – Environmental Virtual Observatories for Connective Actions (EVOCA) – that focuses, among other things, on mobile phone-based information sharing platforms for TTBDs in Kenya. Such integrated approaches may include collaboration and collective actions by many stakeholders directly or indirectly involved in TTBDs control, necessitating a robust means of information sharing and coordination, which may be addressed using mobile phones and other ICT-based tools (Cieslik et al., this special issue). Generally, mobile phones have become new methods for engaging participants through technology, and provide unprecedented ways for participants to have immediate access to their own and others’ observations, fostering effective information sharing (Graham et al., 2012; Now and Nominations, 2011). Because of the utility of mobile phones, there is an urgent need to explore how this technology may be leveraged to address the TTBDs problem.

To effectively coordinate and enhance the collaborations of many stakeholders with divergent views, interests, and perceptions, innovative approaches are critical to improve monitoring, offer extension services, and improve data or information sharing. The advent of the mobile phone and its widespread adoption and usage in many developing countries in African, such as Kenya, coupled with emerging information sharing approaches such as citizen science (Haklay, 2010), could offer a promising pathway to such efforts. To date, most citizen science approaches are well developed and embedded in Europe and other developed countries where mobile phones and citizen science approaches have increased knowledge and understanding of, for example, biodiversity distribution, disease surveillance, and interventions (Haklay, 2010). The term *citizen science* which is also referred to as environmental or participatory monitoring is used here to describe public engagement in scientific activities of collecting and disseminating data driven by a social conscience (Haklay, 2010). In developing countries in Africa, the citizen science approach has just started and is gaining traction. For example, in Kenya and Tanzania, human–wildlife conflicts are monitored and reported voluntarily, either directly or indirectly by the affected citizenry (Graham et al., 2012). However, to embed citizen science in developing countries, there is a need to understand various issues that may negatively impact on the approach, including the existing information sharing culture in an area.

The advent of citizen science approaches and advent of mobile phones could be leveraged in tackling complex environmental and agricultural problems such as TTBDs that have remained a serious threat to human health, food security, and the cultural well-being of many people, especially rural poor pastoralists relying on livestock production. The Environmental Virtual Observatories for Connective Actions (EVOCA) programme of Wageningen University and Research

established in 2015 seeks to explore the potential role of mobile phones and citizen science approaches in addressing several complex environmental and agricultural problems in six case studies in Africa to transform the development landscape. The TTBDs on which we focus in this paper is one of those case studies. EVOCA in Kenya is envisaged to be developed by using an inclusive virtual platform for information sharing that enables effective mapping of the situation, linked to a participatory process that fosters collective action (herein connective action) for effective TTBD control (see Cieslik et al., this special issue). The assumption is that mobile phones and related technologies can be used for collective action – in light of the current lack of information and knowledge sharing, which is perceived to be one of the causes of poor control or eradication of diseases (Allen, 2015; Gustafson et al., 2015). The reasoning is that, in developing countries, formal organisations involved in addressing problems such as TTBDs are often weak and lack sufficient capital or suffer from lack of resources either to effectively control or provide elaborate extension services or to conduct long-term research (Minjauw and McLeod, 2003). Citizen science approaches can empower local people to bypass the need for such formal systems, thereby fostering collective action (Cieslik et al., this special issue). This warrants a critical examination of the views, perceptions, and the information sharing culture of all stakeholders involved in the TTBD problem in order to identify areas where ICT-based innovations can be embedded. In this paper we address the main research question: what is the potential role of mobile phones for sharing information on TTBDs?

In this paper, section 1 & 2 provide an introduction and the conceptual framework in which this study was anchored, while Section 3 provides the methodology that was used to collect and analyse the data. In section 4, we provide the results of our study with the historical perspectives of land ownership and rights issues in Laikipia, setting the scene of how it affects the dynamics of the issues of concern such as (in) security, human–wildlife conflicts and diseases, including TTBDs, and how it shapes the communication landscape in the area. In Section 5, we reflect on the implications of the dynamics of the issues of concern identified on the citizen science (EVOCA) for TTBDs in Kenya.

2. Conceptual framework

In this technological era, the envisioned citizen science platform in Kenya links up to a broader trend in research and practice in which increasingly development interventions are taking advantage of perceived possibilities offered by the digital age, such as the use of mobile phones and other ICT-based infrastructure. A promising example of how development is anchored through digital innovations includes e-agriculture, where farmers, for instance, share information on the control of pests and diseases, market produce, and share knowledge on the best practices in agriculture to further improve their productivity (Mwabukusi et al., 2014; Temba et al., 2016). Other examples include extreme citizen science projects where pygmy hunter-gatherers in the Congo Basin, although unable to read the numbers on banknotes or write their own names, have begun to use handheld computers attached to global positioning systems (GPS) to monitor illegal logging and poaching in their territories (Lewis, 2012; Vitos et al., 2013; Lewis, 2007; Lewis and Nelson, 2006); and, while sharing information, the local people and other entities create networks of communication that can be harnessed to collaboratively improve local resource management (Mwabukusi et al., 2014; Roy et al., 2012). Citizen science for development is thought to hold the promise of empowering local people, opening up possibilities for democracy through participation, and increasing the accountability of governments (Hellström, 2008, 2011) and non-governmental organisations (NGOs) (Lewis and Madon, 2004). Thus, mobile phone-based citizen science for development might be envisaged as a potential *technology of humility* that may be used to spur public participation and the intellectual environment to collectively address common problems affecting people (Jasanoff, 2003a,b).

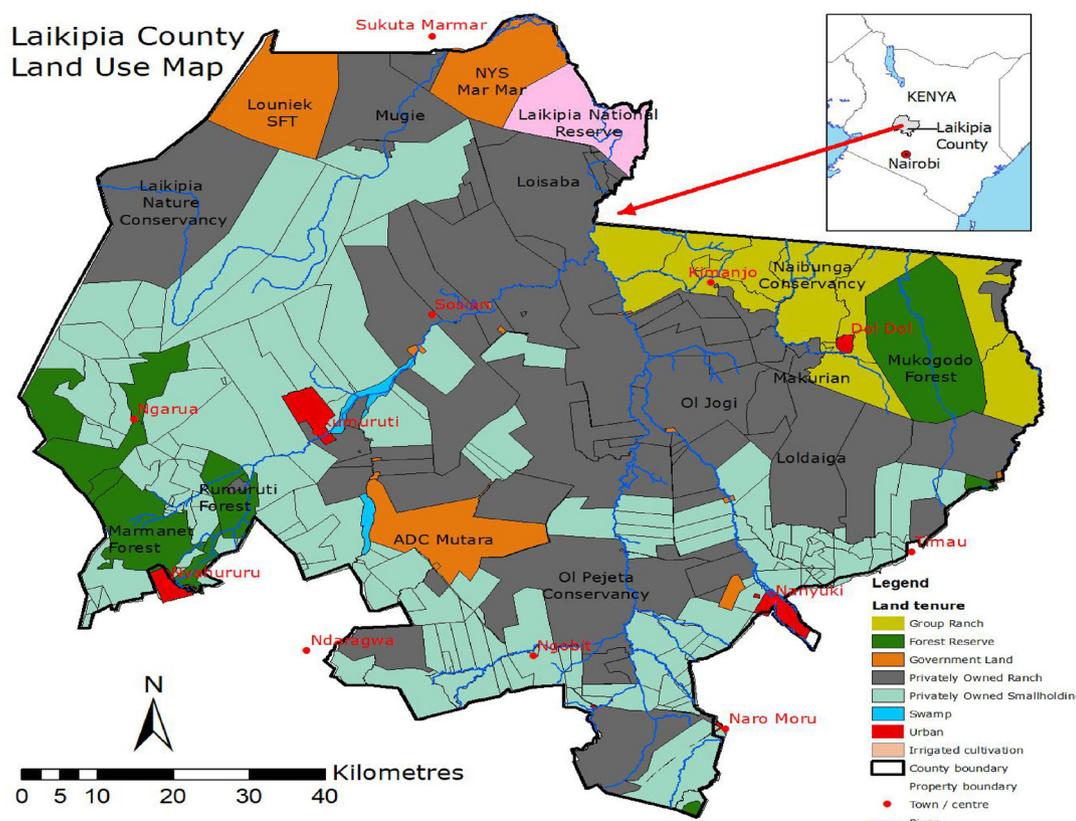


Fig. 1. Map of Kenya showing the location of Laikipia County with various forms of land uses.

Source: There are over 41 private, government or local community-owned ranches in Laikipia. NYS stands for the National Youth Service, while ADC = Agricultural Development Corporation and SFT = Settlement Fund Trustee.

In thinking about the African digital public sphere, postulations of what ICTs and citizen science might mean for African societies frequently draw on modernisation paradigm shifts about the development concept, with development organisations, such as the World Bank (Cohen, 2012), FAO (2001), or Flora and Fauna International (Banks and Burge, 2004) advocating ICTs and mobile phone technology for local people in developing countries to deal with rapid environmental and social change. Looking more closely into these arguments, we find that many reflect a linear, apolitical, and historical discourse on innovation and social change and neglect the social processes and power relations that are inherently part of any innovation and social change process (Kline and Rosenberg, 1986; Roling, 1988; Rip et al., 1995; Rip, 1995; Dormon et al., 2004; Stuver et al., 2004; Leeuwis, 2004). Further literature reviews indeed showed that, in some cases, citizen science and ICT technologies have unintended and unforeseen negative consequences in developing countries, such as exacerbating existing classed or gendered power relations (Britwum, 2009; Orloff, 2009; Etzo and Collender, 2010; Chiumbu, 2012). So, instead of being a technology of humility, in some cases citizen science for development might become a *technology of domination* that reproduces or even exacerbates existing inequalities or negative consequences of the technology, making it necessary to take a critical look at the environment and the potential role of transformative ICT-based tools and processes such as citizen science.

The anticipated citizen science-based EVOCA in Kenya is intended to enable information sharing and to facilitate learning to foster collective action on TTBDs among many stakeholders. These stakeholders have varying degrees of policy, technological, institutional, and organisational issues or power relations that often impede effective control of TTBDs. In this context, there is a need to understand all these complexities affecting a society and the direction of the transformative power of information sharing using mobile phones through citizen

participation. To investigate this, we used RAAIS which is an integrated diagnostic toolkit that has been developed and successfully used to unravel complex issues affecting environmental or agricultural systems and innovations such as pests, diseases, and stakeholder collaborations, for instance, in the control of rice parasitic weeds in Tanzania and Benin, and in the Research Program on Integrated Systems for the Humid Tropics (Schut et al., 2015; Hounkonnou et al., 2012). The RAAIS framework has identified complex environmental or agricultural problems as either affected or influenced by technical, economic, sociocultural, or political issues, making them difficult to solve (Hounkonnou et al., 2012; Schut et al., 2015; Leeuwis and Aarts, 2011). Because the TTBDs are compounded by issues such as land ownerships and management regimes, economic or cultural issues relating to animal husbandry, disease management policy, and stakeholder collaboration, we adopted the RAAIS approach to analyse our data (Schut et al., 2015). Following RAAIS, we started by investigating the historical context of land ownership issues to set the scene for understanding the complexity of the TTBD problem. We then explored the biophysical, technological, sociocultural, economic, institutional and political dimensions of the TTBD problem. We also explored 1) what people identify as a pressing issue of concern; 2) their perception of the cause of the problem; 3) the perceived solutions; 4) how people communicate about these issues to manage them as well as the role of mobile phones in this. Last but not least, we analysed the mobile phone adoption and the changes in the communication landscape. This diagnostic study gave us insights into (i) identifying various issues complicating the effective control of TTBDs, (ii) explore whether and how people in the area use mobile phones to address problems, including TTBDs, and (iii) reflect on what we can expect of the promises of citizen science for the development of mobile phone platforms for addressing TTBDs.

3. Materials and methods

3.1. Study approach and design

We conducted this study in the semi-arid savanna area of Laikipia, Kenya, located at 0°18' South and 0°51' North, 36°11' and 37°24' East (Fig. 1). The county covers ~10,000 km², with an estimated human population of ~400,000 relying mainly on wildlife conservation, livestock production and crop farming (Mizutani et al., 2012; Mwangi, 2013; Bond, 2014a), with many resource-poor pastoral communities living in remote areas characterised by poor transport and communication, and perhaps requiring an effective means of information sharing for their livelihoods. The county has a huge assemblage of wildlife and domestic animals, a recipe for the spread of diseases, with major ramifications for livestock production and wildlife conservation (Keesing et al., 2013; Odadi et al., 2011). The complexity of the activities in the area has attracted many stakeholders involved in various issues related to security, conservation, or livestock production. Some of the major organisations include: Kenya Wildlife Service (KWS), Ministry of Agriculture, Livestock Development and Veterinary Services, International Livestock Research Institute (ILRI), The Institute of Primate Research, The Centre for Disease Control, local and international research institutions, and extension service providers. Despite the efforts of many stakeholders, TTBDs continue to be a major challenge to many farmers in the area, and there is a critical need to explore the extent of the problem and to determine the potential of mobile phones for information sharing to address the problem.

Prior to the main study, we conducted a reconnaissance study in the area between October and December 2016. The objectives of the reconnaissance study were three-fold: to (i) gauge and understand the extent and the dimensions of the issues underlying TTBD control, (ii) identify the stakeholders involved in TTBD control, and (iii) purposefully select informants for the in-depth interviews and possible translators. We used the results of the reconnaissance study and the outcome of workshop proceedings to develop themes that were used to conduct in-depth interviews. We also conducted an extensive literature review prior to and during the reconnaissance study to gain insights into various issues underlying the TTBD problem. As the involved stakeholders emanate from organisations, farmers, and extension service providers operating at various levels in different parts of the study area, we used a multi-stage sampling protocol.

Being interested in general issues surrounding TTBD control, the information sharing culture, and stakeholder collaboration in the area, we used ethnographic methods such as in-depth interviews, field observations, and document reviews (Paschen and Ison, 2014; Baxter and Jack, 2008; Yanow, 2009), as opposed to random sampling protocols (Bowen, 2008). The choice of these ethnographic methods was premised on the general understanding that how people 'story' their past experiences and actions will ultimately determine their future practices and adaptation towards problems (Yanow, 2009). Informed by the reconnaissance study and the workshop, we identified and broadly classified the stakeholders responsible for TTBD control as either: governmental or non-governmental agencies, smallholder agro-pastoral farmers, large-scale commercial farmers, and private extension service providers commonly referred to as agro-veterinarians (agro-vets). We used the stakeholder classification to systematically and purposefully select interview informants at two levels (i) stakeholder category and (ii) localities in which the identified stakeholders operate: in general, rural or remote agro-pastoral areas, urban centres, or large-scale commercial ranches.

3.1.1. Workshop

Because of the central role of this study and the EVOCA project in the area, the first author was nominated by KWS to attend a stakeholder workshop in November 2016, dubbed The Laikipia County One Health Initiative. The overall objective of the workshop was to bring all

stakeholders together to develop a common approach to address zoonotic and TTBD problems in the area. The workshop was instrumental in shaping this study because (i) it elucidated the TTBD problem and shaped the interview approach, (ii) it included stakeholders involved in the management of disease problems, (iii) it identified the agro-pastoral framers as forming the critical pool of those affected by zoonotic diseases, including TTBDs, (iv) it led to the formulation of the way forward, and action plans prepared after the workshop provided contacts and opportunities for future stakeholder engagements. Some of the data used in this study were derived from the information garnered at the workshop.

3.1.2. In-depth interviews

Informed by the reconnaissance study and the informant selection protocols, the in-depth interviews were conducted between January and August 2017. The interviews were conducted using a dialogue approach and revolved around a set of discussion points identified. A total of 24 individuals from the various stakeholder categories identified were approached to take part, and 21 respondents consented, with each interview taking one and half hours on average. Two women and one man from the agro-pastoral communities declined to be interviewed citing personal or family issues. Because the emphasis of this study was on obtaining quality information from the in-depth interviews rather than on quantity, we maximised the diversity of the respondents representing the various stakeholders identified. The dialogue revolved around thematic issues such as informant characteristics (age, occupation, locality), land ownership and security issues, human-wildlife conflicts, animal diseases, TTBD control practices, among others.

To derive a clear picture of the information sharing culture in the area, informal discussions were tailored to include discussions on people, events, and timelines of various issues or activities that either directly or indirectly affected them and their perceived solutions. Informant characteristics such as age (young/old), sex, income (poor/rich), locality, or occupation were deemed important as they reflect diversity, influence stakeholder collaboration and power relations, and inform the local information sharing culture (De Bruijn, 2009; Etzo and Collender, 2010; Graham et al., 2012).

The respondents comprised local nomadic pastoral herders ($n = 10$), commercial ranch managers involved in either livestock or wildlife conservation initiatives ($n = 4$), government officials involved in livestock extension activities ($n = 3$), and agro-vets ($n = 4$) involved in the sale of livestock vaccines and pesticides such as acaricides in Laikipia county. The age of the respondents ranged from 19 to 59 years, and their education level varied from illiterate (never attended school) to tertiary (university level and others with professional qualifications in veterinary, animal health, and social development work). Agro-vets interviewed were mostly located in urban centres where their shops or offices are located. The local community leadership such as the chiefs were also interviewed as they form an important policy link between the local governmental and non-governmental agencies responsible for addressing various societal issues that affect people in the area.

The interviews were conducted primarily in English, but, when the interviewee could not adequately communicate in English, they were conducted in either Kiswahili or a local dialect to avoid loss of indigenous knowledge or information through the respondent's inability to communicate in the English language. Because the interviews took a long time and exhausted the memory of the Philips Inc. MP3 recorder, the interviews were instead recorded in a field notebook as "statements" from the respondents. The decision on the optimal number of respondents was based on the quest to obtain diverse stakeholders up to the point at which no new information was observed in the data (Ness, 2015; Bowen, 2008). The dialogue approach was preferred as it enabled the researchers to learn and reflect on the issues being discussed and allowed the informants to provide information that could be perceived to be either socially, institutionally, or politically sensitive. To address

confidentiality issues, the informants' names were anonymised for ethical reasons. The interview notes were later analysed using qualitative approaches.

3.1.3. Field observations

To learn about the activities of the stakeholders in their natural settings, we accompanied some agro-pastoral farmers on four (4) occasions, each taking a day, while on their routine activities such as herding livestock (e.g., cattle, sheep, goats, and camels), purchasing products at agro-vet stores, or spraying their livestock with acaricides. This approach also enabled us to interrogate some of their activities with a view to gaining more insights, which might not be possible without participation. We took some photographs of the activities in which we participated.

3.1.4. Document reviews

To gain a greater understanding of the various topical issues in our study and to corroborate the information obtained from other approaches, we reviewed ~70 published documents obtained via the Google Scholar search engine and ~10 unpublished documents. The unpublished documents comprised wildlife and livestock management plans, farm records, diseases and epidemiological reports, and websites of telecommunication companies such as Safaricom Plc, Airtel-Kenya, and Telkom-Kenya. Review of these documents followed Bowen's (2008) guidelines.

3.1.5. Data analysis

As we were interested in unravelling the extent of the TTBD problem and issues complicating its effective control, we adopted the framework and guidelines of the Rapid Appraisal of Agricultural Innovation Systems (RAAIS) (Schut et al., 2015). Our data were primarily qualitative, and therefore we classified the datasets from the informant interviews, field observations, document reviews, and workshop into various dimensions that characterise complex environmental or agricultural problems. Using RAAIS, we developed a matrix where we classified the issues that affect people in the area, including TTBDs (complexities) and their dimensions, with a view to also identifying necessary information gaps where innovations such as mobile phone usage might be embedded to address the problem.

4. Results

4.1. Historical perspectives of land ownership and issues in Laikipia, Kenya

Land ownership and land rights in Kenya became a fundamental political and economic issue after the country's independence from Britain in 1963, with implications for various issues such as security for humans and animals, human-wildlife conflicts, and disease transmission, including TTBDs. During the pre-colonial period, land in many areas in Kenya, and particularly in Laikipia, was primarily managed as communal property by nomadic pastoral communities who traversed the vast semi-arid county herding their livestock. The human population in the area at that time was composed of small pastoral communities, mostly reliant on livestock nomadism (Mizutani et al., 2005; Letai, 2011). Culturally, nomadic pastoral communities such as Maasai, Samburu, Turkana, and Borana traversed the various counties unrestricted in search of pasture and water for their animals, especially during the dry season (Lesorogol, 2003; Bond, 2014a; Lengoiboni et al., 2010). They probably had sufficient pasture and water for their animals. Land ownership and boundaries in pastoral areas were defined by tribal or ethnic groupings, kinships, and family lineages (Lesorogol, 2003; Osamba, 2000).

However, during the struggle for, and the partition of, Africa by European powers around the turn of the twentieth century, British imperialists in Kenya, either forcibly or through agreements such as the British-Maasai agreement of 1904, removed the pastoral Maasai,

Borana, and Samburu communities from the greater Rift Valley region, including from the Laikipia, Samburu, and Isiolo areas (Hughes, 2015). In the process, many nomadic pastoral communities lost access to their ancestral grazing areas, affecting their culture. For example, some members of the Maasai community, ostensibly those perceived to be hostile to the settlers' establishment, were moved from Laikipia to the southern part of Kenya, in the present day Maasai Mara, an area that extends into the Serengeti Plain, which is located mainly in Tanzania (Hughes, 2015). The land annexation and adjudication that followed led to the delineation of land ownership boundaries and the establishment of large-scale commercial farms, commonly referred to as ranches.

When Kenya won independence from Britain in 1963 and following the subsequent return of many British settlers to Europe, the new government in Kenya began to nationalise land and re-distributed vacant parcels to indigenous communities. The new arrangement was hailed by many Kenyans as a nationalistic move, but these schemes were soon criticised by others for putting the vacant parcels of land in the hands of a few well-connected political elites (Syagga, 2011; Letai, 2011). In Laikipia for instance, most local nomadic pastoral herders were settled on small landholdings in the west or remained landless. In this process, group ranches in Laikipia county such as Tiemamut, Lekurruki, Koiija, and Ill'Ngwesi, in Laikipia North, were collectively allocated to the remaining Maasai, and the remaining parcels were retained by the white settlers (Bond, 2014a; Letai, 2011). Large-scale commercial ranches legally held by settler farmers under a 99-year lease agreement with the government of Kenya form the main ownership type and vary in size from ~ 5000 and 100,000 acres (Letai, 2011).

The rapid population increase in Laikipia after independence had serious implications such as dwindling land parcel sizes and reduced pasture for water and animals. Land ownership therefore became a pressing political mobilisation tool in Laikipia. In Kenya, three major forms of land tenure systems are recognized by the Kenyan laws: public, communal and private properties. The proof of land ownership is a sacrosanct document-title deed (Letai, 2011). The land tenure systems and rights often influences the various land uses in Laikipia. Because the immigrant communities are in pursuit of pasture and water for their animals, they move and invade private, public and communal land, and without land ownership documents, it constitutes an illegality. The loss of grazing areas reduced the pastoral communities' ability to make their livelihood. Because of political agitation, the increasing human population, and poor access to social and economic activities, some communities resorted to illegal invasions of private and government land, resulting in increased insecurity. Insecurity in this context is defined a bridge of peaceful co-existence among people in an area and is sometimes characterised by violent conflicts alternating with negotiated settlements (Bond, 2014a). Insecurity and large-scale movements of domestic animals in the area have also led to increased human-wildlife conflicts due to displacement of wildlife from their habitats, and a consequence, it promotes the spread of TTBDs (Keesing et al., 2010). Land ownership and rights, and mobility of wildlife and domestic animals, have aggravated the complexity of security, human-wildlife conflicts, and disease transmission.

Most of the informants cited and ranked the lack of security, which is often characterised by private land invasions by nomadic pastoral communities and cattle rustling, fear of attack and damage by wildlife, and the transmission of notifiable diseases as the most pressing local issues. They reported that land invasion normally increased during the dry season when pasture and water are scarce, that armed invaders often moved around with large herds of animals, and that they constantly lived in fear of possible attacks by them. The residents also complained that, because of huge assemblages of wildlife in the area, they also feared attacks from wildlife resulting in human death or injuries, crop and property damage, and transmission of diseases to humans and their domestic animals. The residents of the area cited diseases such as foot and mouth, brucellosis, rabies, and ECF as the most

Table 1
Overview of identified issues of concern affecting people, perceived solutions, and information gaps.

Pressing issue identified	Perceived cause of the problem	Perceived solutions	Information sharing before advent of mobile phone	Current method of information sharing	Type of information shared	Information gaps
Security issues (land activism, cattle rustling, and indiscriminate movement of domestic animals)	Cultural practices among pastoral communities, water and pasture scarcity	Improved collaboration between security and wildlife conservation agencies Government to control haphazard movements of livestock from neighbouring areas Improved education levels among pastoralist communities Pay compensation claims Improve stakeholder collaboration	Word of mouth – <i>serian</i> amongst the local Maasai community used messages referred to as <i>Olkilinkwai</i> Radio calls, letters, faxes for government institutions responsible for addressing the problem, such as the police	Mobile phones and radio receivers	Sightings of movement of herders and their livestock	TTBD distribution and eco-epidemiology at human-wildlife-livestock interface Tick control strategies
Human-wildlife conflicts reporting to responsible agencies	Movement of wildlife, human deaths and injuries, crop and property damage	Data and information sharing on wildlife movements, crop and property damage Public education and extension	Word of mouth – <i>serian</i> amongst the local Maasai community used messages referred to as <i>Olkilinkwai</i> Radio calls, letters, faxes for government institutions responsible for addressing the problem, such as the KWS	Mobile phones, radio calls, and emails	Human deaths, injuries, crop damage, depredation damage	Wildlife movement patterns Location of watering points
Zoonotic diseases occurrences (foot and mouth disease, brucellosis, rabies), TTBDs-East Coast fever (ECF).	Lack of information on availability and prohibitive cost of animal vaccines High livestock stocking rates (cultural practices) and lack of markets for farmers Lack of disease diagnostic tools	Improve coordination and information sharing Government to offer incentives and subsidies to farmers Provide information to farmers regularly through field extension services or mobile phone alerts Reduce livestock densities among pastoralist communities Provide markets for framers to dispose of excess livestock Provide information on location of laboratory and diagnostic services	Reported by making visits to local government livestock officials Field visits, workshops, and seminars Visit to livestock auction markets Reliant on government extension services	Unstructured and irregular meetings Radios, irregular extension services, unstructured mobile phone usage (calling, texting) Visit to livestock auction markets	Zoonotic and other notifiable diseases Availability of acaricides and vaccines Symptoms of disease in domestic animals, animal health status Market prices of livestock	Data and information on TTBD and wildlife-livestock diseases Provide market prices of vaccines Provide comparative market prices for their animals Provide information on location of laboratory and diagnostic services

Table 2
Overview of the extent of the TTBD problem in Laikipia, Kenya.

Identified TTBD problem dimension	Biophysical	Technological	Sociocultural	Economic	Institutional	Political
Description of the problems	Massive reproduction and resilience (adaptations) of ticks to extreme environmental and human conditions. Host-pathogen characteristics invasive plant species (<i>Opuntia stricta</i>)-attract tick hosts	Inability to determine, and cost of determining, the efficacy of TTBD control methods Lack of mechanised systems for spraying ticks Growing resistance of ticks to chemical acaricides	Cultural practices by nomadic pastoral communities, e.g. Maasai, Samburu, and Borana	Lack of sufficient monetary outlay by farmers and costly prevention of TTBDs	Divergent policies, views, and power relations issues slow implementation of TTBD strategies	Two-tier structure of the Government of Kenya (national and county) level with unstructured reporting or information sharing frameworks, political issues surrounding livestock management and land activism.
Causes of the challenges	No control mechanisms for TTBDs in wildlife Land-use activities (interfaces between wildlife and domestic animals) Lack of information on TTBD distributions	Lack of data or information on acaricides' efficacy resistance Insufficient information on resistance of livestock breeds to tick attack and infestation of livestock Inability to identify tick species and pathogens transmitted Infrequency or failure by farmers to follow instructions on acaricides applications Lack of disease diagnostic tools and information	Lack of awareness on the negative impacts of high livestock stocking densities and TTBD control	Decentralisation of responsibility for TTBDs from government to farmers World Bank SAP programme removed subsidy Lack of funding for systematic research on TTBDs Poor farmer-oriented extension services Poor infrastructure and communication	Conflicting or competing interests of wildlife and livestock management and research institutions Lack of knowledge and awareness	Competing interests of national and county government and skewed resource allocation Insecurity: land invasions, human-wildlife conflicts Poor institutional linkages and collaborations Limited funding and resource allocation by national government to devolved units of government and institutions

common diseases spread from wild and domestic animals. The TTBD issue, despite being a problem, did not feature prominently in their discussion as they were often preoccupied by the identified issues of concern that takes precedence among the local people and were more often talked about and share information about them because they wanted them addressed by the government or other relevant stakeholders. The informants also suggested solutions to these issues (Table 1). These issues will be elaborated successively in the preceding sections of this paper.

4.2. Descriptions of the TTBD problem and challenges in Laikipia, Kenya

Although TTBDs did not appear to be the most pressing issue for the residents, we explore the extent of the problem dimensions of TTBDs, their challenges and their perceived solutions derived from the interviews, field observations, and document review (Table 2).

4.2.1. Biophysical dimensions

Biophysical characteristics refer to either biotic or abiotic factors that make complex agricultural problems such as pests and diseases difficult to control (Schut et al., 2015). Biotic and abiotic factors such as the massive reproduction of ticks, resilience to hostile environments (extreme temperature, humidity, and vegetation), and their multiple species and multi-host and pathogen adaptations (Medlock et al., 2013; Riginos et al., 2012; Keesing et al., 2010) make TTBDs a complex problem to solve. Interviews with agro-pastoral farmers, large-scale commercial farmers, and livestock and veterinary extension officers revealed that agro-pastoral farmers, despite their experience with pastoralism, have limited or vague knowledge on TTBD ecology compared to either the large-scale commercial farmers or the extension officers. Because of their limited understanding of TTBD characteristics, we observed that agro-pastoral farmers infrequently applied acaricides, ignored prescriptions on acaricide usage, and kept large numbers of livestock without corresponding farm inputs. Agro-pastoral farmers, unlike large-scale commercial farmers, mainly took action when ticks were visible in their adult stages and full engorged, ignoring other critical life stages. From their long-term experience with livestock and wildlife issues, agro-pastoral farmers could vaguely identify tick species based on their morphology and body colour. Large and small-scale farmers in the area seem to understand the relationship between common invasive plant species such as *Opuntia stricta* and the spread of TTBDs. Invasive plant species generally attract foraging tick hosts and increasing their interfaces, aggravating TTBD transmission. Unlike large-scale farmers and other officials, agro-pastoral farmers interviewed showed either a limited understanding of, or complicity in, land-use practices such as land invasions in which fences and barriers are breached, affecting host movements and TTBD transmission. All informants generally acknowledged tick resistance to acaricides and often changed brands to enhance their efficacy. Farmers were also aware that indigenous breeds of livestock such as Boran cattle were probably more resistant to TTBD attacks compared to exotic breeds such as Friesian or Guernsey. Unlike large-scale farmers, agro-pastoral farmers blamed wildlife more for the spread of diseases.

4.2.2. Technological dimensions

Technological dimensions refer to the role that improved technology can play in addressing agricultural issues (Schut et al., 2015) by increasing efficiency and reducing the operating costs in agricultural systems (Schut et al., 2015). For example, different TTBDs are difficult to positively identify because of their similarity in symptoms or are sometimes asymptomatic, but they can be positively diagnosed if testing kits are readily available (Minjauw and McLeod, 2003). In the interviews, farmers complained that they administer drugs to their animals based only on observable symptoms, which in most cases may be confusing. The misapplication of drugs may make TTBDs difficult to control and often leads to mortalities. There are no animal disease

diagnostic laboratories in Laikipia, and farmers rarely consult them, unless through government interventions when massive outbreaks are reported. Farmers in the area are possibly administering drugs to animals based on assumptions rather than on confirmatory tests. We also observed that large-scale farmers used mechanised spray pumps and spray races, which appeared effective and less time consuming, as opposed to agro-pastoral farmers who relied on hand sprays. Unavailability of, or failure by farmers in the area to consult or utilise, technology to either diagnose or take appropriate actions on TTBDs seem to be some of the problem dimensions that undermine their effective control.

4.2.3. Sociocultural dimensions

Sociocultural-related dimensions reflect the long-standing practices and beliefs that people espouse in an area (Schut et al., 2015). Practices by people in an area may influence behaviour and how people perceive or do certain things, despite the various improvements that may have occurred over time. Because of general practices or past experiences, many people may become fixated with past traditions, making them complacent in addressing issues. Field observations showed that pastoralists in the area culturally keep high livestock numbers without any corresponding capital investments such as improved animal husbandry and control of diseases, including TTBDs. The repercussion of such a practice is poor TTBD control resulting in heavy infestation and increased livestock mortalities. We observed that, in contrast, large-scale farmers in the area, as a best practice, matched resources with their stocking densities.

4.2.4. Economic dimensions

Economic dimensions relate to issues of cost and benefit analysis, which often have implications for addressing complex agricultural problems (Schut et al., 2015). Interviews with farmers and extension officers revealed that generally farmers are affected by a lack of funding for their operations and a lack of markets for their livestock. They complained that the removal of subsidies, increased taxes, and the decentralisation of livestock issues from the government to farmers following recommendations of World Bank-led structural adjustment programmes (SAPs) had particularly increased livestock production costs. The increased cost of production has a multiplier effect on the ability to control diseases in animals. Furthermore, lack of funding for systematic research on TTBDs was reported by the extension officers as a challenge to their effective control. The decentralisation and the increased costs of operations have demotivated farmers, and, as expected, farmers rarely consult government extension services in the area. A clear understanding of the economic dimensions of TTBDs is critical for informed decision making.

4.2.5. Institutional dimensions

Institutional dimensions relate to institutional arrangements, policies, regulations, and interests that govern the way institutions operate in a country (Schut et al., 2015). Institutional set-ups may affect institutional collaborations and power relations, factors that have been identified as critical in addressing complex agricultural problems and innovations (Kilelu et al., 2013; Schut et al., 2015). Lack of direct engagement and of extension service provision to farmers affects stakeholder relationships and institutional linkages, hampering data and information sharing (Schut et al., 2015). In Kenya, it is the responsibility of the government to control diseases, but interviews with government officials showed that lack of funding for their operations and of extension services have hampered their quest to help farmers. Government officials interviewed complained that they were poorly resourced and rarely provided on-farm extension services or visits to farmers. We observed that there are ~ 5 extension officers in the area and that these had to travel by motor cycle. They complained that motor-cycle use was life-threatening because of the presence of dangerous wildlife and that they need security support to carry out their

duties. The large-scale farmers, however, indicated that they had the institutional capacity to link up with researchers, extension services providers, and livestock drugs manufacturing companies. In contrast, we observed that small-scale farmers lacked information on the availability of drugs and other extension services. Therefore, to effectively address TTBDs in the area, there is a need to develop ICT-based innovations that will allow stakeholders to freely interact and share data and information.

4.2.6. Political dimensions

Political dimensions refer to attributes relating to management structures and the span of control of the organisations involved in a problem (Schut et al., 2015). The political dimensions of the TTBD problem are particularly important because different institutions have different spans of control at local, national, or regional level, and this often affects decision-making processes, information exchange, innovations, and action (Kilelu et al., 2013). Interviews with the stakeholders and the workshop participants showed that stakeholders involved in TTBDs operated at local, national, or international level. The stakeholders represented government, NGOs, and research institutions such as KWS, county government, and national government. From the informant interviews, some challenges identified included: suspicion and lack of trust, stringent regulations about sharing data among institutions, and lack of structured systems of engagements among the stakeholders. We found that institutions submit reports on disease issues in the area internally within their institutions, with few interactions across institutions. Farmers in the area share information with the government on some notifiable diseases such as foot and mouth disease and rabies because this elicits government intervention measures. We also observed that farmers in the area report TTBDs to private agro-vets only to acquire vaccines for their animals and rarely, if ever, to government officers as this is not deemed worthwhile (motivational issues). To share such information across and within organisations, ICT-based tools such as mobile phones may provide an opportunity for co-ordinating all stakeholders in the area for surveillance and action across the organisations responsible.

4.3. Information sharing culture and changes in communication landscape

From the analysis of the identified dimensions and the challenges of the TTBD problem, here we present the possible solutions and gaps that exist in the spectrum in order to apply ICT-based tools such as mobile phones and citizen science approaches to the problem (Table 2). Using the local Maasai pastoral farmers as an example, we provide a short historical context of the information sharing culture that has existed in the area and how the adoption of mobile phones has changed the culture, with implications for citizen science.

4.3.1. Traditional approaches to information sharing

Interviews with the local nomadic pastoral communities showed that, since time immemorial, they have had informal networks to address issues of concern in the area. Information sharing was commonly by word of mouth, often referred to as *serian* and the message was referred to as *Olkilinkwai* by the local Maasai community. This mode of information sharing was probably then the only effective way in which communities could share information. Interviews with the local Maasai also revealed that, to maintain confidentiality, some sensitive information was maintained between trusted kinsmen and friends or neighbours using trusted messengers commonly referred to as *Olkipaaret*. The messengers often travelled over long distances on foot to deliver the information. For example, some local pastoral community informants recalled that selected messengers moved across villages to share information on the repercussions of the severe droughts of 1984 to enable people to seek areas to which to move. Similarly, such methods were used to share information during the *El Nino* period of 1997, as most people in the area had not acquired phones because of

poor mobile phone infrastructure and the prohibitive prices of phones. Other forms of information shared included outbreaks of livestock or human diseases.

Formal modes of information sharing included the use of letters, faxes, telegrams, and radio communication. For example, most of the governmental and non-governmental offices and large-scale commercial ranches that we visited relied heavily on print information, as exemplified by the many files and registries in use. Reports are literally prepared and kept on file, although we were informed that attempts are being made to digitise the records.

4.3.2. Mobile phone adoption and communication landscape

The rapid adoption of mobile telephony in Laikipia began in the year 2000, when mobile phones became more affordable and accessible to the area's residents. All the informants reported that they acquired their mobile handsets between 2003 and 2010. This probably coincided with the rapid phase of mobile phone adoption in several other areas in Kenya. Since then, the local pastoral herders seem to have reduced the use of physically mobile messengers to relay information and have opted instead to use mobile phones to share information. Mobile phone adoption rate in the area is ~70%, compared to Kenya's national average, ~66% (CIDP, 2016) and reflects the adoption rates in Kenya's Rift Valley Region, where Laikipia county is situated, as reported in the Demographic Health Survey data for 2014 (Kenya National Bureau of Statistics et al., 2015). We could not, however, ascertain the approximate percentage of smart or simple phones used in the area but the choice of a smart phone was generally influenced by factors such as better access to power to the charge phones and higher literacy levels and lower age of users.

Interviews were conducted with some local pastoral farmers such as Masikonde, Kipish, and Kirobi (pseudonyms) from Laikipia North. Masikonde, a 40-year-old Maasai pastoralist from Laikipia North, described how he uses his phone:

"I have now become addicted to phones. I call family members, friends, and even the livestock extension officers for help when I see unusual diseases in my herd. I also call the agro-veterinarians explaining the symptoms of the diseases and from there I am advised what drugs to buy or, if possible, I ask him to deliver it to where I am because I can direct him via my phone to our grazing fields. So, I don't have to travel looking for him. When the livestock officers in the area cannot be reached, we call the director of livestock or the chief if we have his number or, if we don't have it, we solicit his number from friends. The phones have thus made our work easier and faster. We no longer have to trek over long distances looking for our friends or the veterinarians for information." Masikonde's statement is an assertion shared by many pastoralists that we encountered in the area. The information shared by mobile phone includes: (i) location of forage and water for livestock, (ii) livestock health status report from the grazing fields, (iii) location of wildlife predators, and (iv) information on schedules of livestock auction markets, among other things. This example illustrates that the communication landscape among the agro-pastoral farmers in the area has changed with the advent of the mobile phone. The agro-pastoral farmers asserted that mobile phone use has reduced their travel distances and provides quick access to networks of practitioners who are able to help them solve the issues affecting them.

Interviews with Elijah and Francis (pseudonyms), agro-vets, and livestock health officers in Laikipia North also confirmed this trend. They reported that unlike before – when they used to literally move from one point to another – they are now regularly in contact with the livestock herders with access to mobile phones. Livestock herders describe symptoms or send pictures to the agro-vets, and these give advice based on this virtual information. The agro-vet officers interviewed also stated that they offer extension services by regularly communicating and sharing information with farmers on diseases and on possible vaccines for their animals.

Interviews with officials from government agencies responsible for

wildlife conservation and livestock revealed that people often call different agencies to seek support in urgent cases such as cattle rustling incidences, wildlife attack, or flooding. Mobile phones are also used by officials in the area to answer public queries and attend to issues raised by the residents, and through regular engagement they build trust with the officials on some issues. For example, the agro-vets reported that they occasionally receive reports about human-wildlife conflicts and redirect them to KWS as they have their contacts. From our experience in the area and interviews with KWS personnel, people predominantly use mobile phones to report human-wildlife conflict incidences. Taking cognisance of these developments, KWS has emergency mobile phone numbers, called hotlines, dedicated to receiving information of human-wildlife conflicts and compensation cases. The incidences are used to prepare reports for: (i) compensation requests to the County Wildlife Conservation and Compensation Committee, (ii) management purposes such as to generate conflict hotspot maps, and (iii) informed decisions on the deployment of personnel and resources to combat human-wildlife conflicts in the area. Some details captured on human-wildlife conflict incidence reports include the date of the incident, locality or GPS coordinates, species of animal responsible, type of damage occasioned, and actions taken by KWS or any other agency that may be involved in addressing human-wildlife conflicts.

According to the interviews and observations, local people in Laikipia have also subscribed to various money wallets such as M-PESA, Airtel money, and Telkom money for economic reasons (<https://www.safaricom.co.ke/business/corporate/m-pesa/>). The use of mobile phone wallets in the study area provides another dimension and illustration of how mobile phones are becoming tools of economic empowerment, especially among rural poor agro-pastoral communities.

From the interviews, mobile phone use in the area has enabled local farmers and stakeholders to develop networks across international boundaries. Sepeika (pseudonym), a 49-year-old local area chief from Laikipia North provided an interesting dimension of how mobile phones have radically changed his life and that of others in the area. He bought his first mobile phone in 2006 and since then he has used it for his official work and domestic chores: *"In my honest opinion, the mobile phone has changed my life dramatically. I have now upgraded my phone to a smart phone, and I can now read emails and be on social media at all times. I have a sister working with the Kenyan Embassy in London, and I can call her anytime I feel like. I am always updated about what's happening in the UK, and I have made new international friends linked to her through WhatsApp and Facebook applications installed on my phone. Her friends also chat with me, inquiring about issues in our area concerning wildlife, security, and features of interest in the area because they want to tour the area. I also organise meetings such as the grazing committee meetings to agree on how to share scarce pasture and water for our animals and access to these resources in the neighbouring commercial ranches. Before, it was impossible to have such linkages, but the phones have made it possible. My life without a phone is now unbearable. I can live in any place however remote or hostile as long as I have a phone with subscriber connectivity. However, part of my work has also been made difficult because land invasion in the area is most probably organised by people who readily share information using mobile phones about the availability of pasture and water. It is also difficult to control them since they share information about the movement of various security teams more easily and evade them."*

Sepeika (pseudonym) thus provides a candid example of how mobile phone connectivity has shifted networks from local to international level. For example, some pastoral livestock herders have a fast and direct linkage to local governmental and non-governmental agencies and to international ones such as Oxfam, SNV-Dutch International, and World Vision to address issues such as livestock production, drought resilience mitigation, financial funding and economic empowerment, and other issues relating to insecurity such as cattle rustling. The fast access to such local and international development partners, as evidenced by Sepeika, shows how mobile phone usage has revolutionised linkages and reduced the distance between local farmers and development

partners at local and international level. Furthermore, the residents of Laikipia informed us that the drought periods of 1984 and the *El Nino* phenomenon of 1997, which many still recall vividly, were more catastrophic because of limited access to information and emergency services. However, similar catastrophic events such as the 2009–2010 drought were tempered by faster responses and interventions by local and international stakeholders, courtesy of mobile phone use.

From the interviews and observations, mobile phone applications commonly used in the study area include: voice call, texting, photography, social media applications such as WhatsApp or Facebook. In Laikipia North, for instance, we came across WhatsApp groups such as *Kiyaap*, *Ol Lentile*, or *Nasaruni*, which are youth or conservation-oriented groups where topical issues such as prevailing weather conditions, job advertisements, politics, farming, and conservation issues are discussed. In the process of our interviews, they voluntarily included the first author of this paper in all three WhatsApp groups after learning that he originated from an organisation involved in addressing human–wildlife conflicts, one of the key problems in the area.

The use of mobile phones is widespread in Laikipia, with a penetration of ~70% (CIDP, 2016), but this implies that 30% of residents are excluded (disconnection) from access to mobile phones. Various informants acknowledged that they knew of friends, kinsmen, or kinswomen without phones, and that they could be thereby disadvantaged. The spatial distribution of mobile phones in the area cannot be formally ascertained; rather, we relied on informants' statements that indeed there are some people in the area without phones or access to phones. The residents without mobile phone access could represent a sizable proportion of people excluded from the existing information sharing network of users and stakeholders, with implications for their access to socioeconomic activities and to timely information on other issues of concern. There are certain remote areas in Laikipia where there is no mobile phone connectivity. Respondents indicated that access to mobile phones is also hindered by a lack of mobile phone infrastructure such as electricity to charge phones, connectivity, and prohibitive prices. We observed several mobile phone charging shops in the study area, especially where electricity or solar power were limited.

In interviews, three local Maasai *morans*, pseudonyms: Loosenka (50 years old), Joseph (30 years old), and Lekamario (27 years old), whom we found herding livestock in the thickets of Laikipia North, individually stated that they had never attended school but had mobile phones to connect to their families or to monitor the availability of pasture and water for their domestic animals. They also reported that they had a network of other pastoral farmers with whom they keep in touch to share and appraise information regularly, especially on security, wildlife, and the health status of their livestock. According to these three illiterate men, literacy levels were not a hindrance to the general use of mobile phones but impeded applications such as texting. We observed that they had simple phones sufficient to meet their needs, implying that the adoption and use of mobile phones is also influenced by individual users' literacy level. Other informants such as governmental or NGO officials and extension workers all had smart phones. Contrary to our expectations, we also encountered school-going young men and women with mobile phones.

From the documents analysed, such as county integrated development plans, the wildlife conservation and management strategic plan (2012–2017), and integrated livestock development plans, we found that most of the issues addressed in these documents corroborated the results of our interviews and field observations. Almost all the documents mentioned water and pasture issues, human–wildlife conflicts and diseases, land use, infrastructure and development, and youth development. All these issues have either a direct or an indirect bearing on TTBDs.

5. Discussion and conclusion

This study assessed the potential for the citizen science EVOCA

project, which is envisaged to be developed in Laikipia, Kenya. We therefore aimed to (i) identify the issues complicating the effective control of TTBDs (ii) ascertain whether and how people use mobile phones or other methods to address these issues, and (iii) reflect on what we can expect of the promises of citizen science for the development of EVOCA.

5.1. Issues of concern and mobile phone usage

The advent and use of the mobile phone in many African countries was motivated by the assumption that mobile phone technology would present new opportunities for development and the empowerment of people (De Bruijn, 2009; Lewis et al., 2016). Access to communication technology was expected to “develop” Africa thanks to the opportunities that supposedly came with the technology. Thus, a major change was expected in the social and political sphere, namely, by diminishing distances and increasing connectivity (though not always and not for everybody) between people by using mobile phones (Asongu, 2013; De Bruijn, 2009).

This study in Laikipia has provided insights into the TTBD problem in Laikipia, suggesting:

- (i) that TTBDs, despite being a problem, are not considered to be very important compared with other issues that are apparently ranked by residents as more pressing. Issues such as insecurity characterised by land activism and property damage, cattle rustling, human–wildlife conflicts, and the spread of zoonotic diseases relegate and make the TTBD issue less problematic in people's eyes, influencing what people communicate and share information about. The TTBD problem is compounded by a combination of biophysical, sociocultural, economic, institutional, and political-related problems, making their control difficult.
- (ii) that lack of structured data and information sharing, of coordination of stakeholders, and of policies on disease management remain impediments to TTBD control, and mobile phones and citizen science can be leveraged to partly address the problem.
- (iii) that the mobile phone adoption rate in the area is ~70%, compared to the national average in Kenya of ~66%, suggesting that mobile phones (simple and smart) are widely used by people for various socioeconomic activities, despite the residents being classified as poor. In addition, some people who do not own a phone have reported owning SIM cards, suggesting that phone use is even higher than these statistics. SIM card ownership by people who do not own a phone enables them to access services and may increase the observed adoption rate of mobile phones in the area.
- (iv) that mobile phones are widely used in the area to communicate with family members and friends and to access information on the pressing issues of concern, forming issue-based communication networks. The use of mobile phones for economic activities such as business and banking services has empowered people economically, improving their livelihoods, whereas those without access are probably excluded (disconnected).

Although the advent of the mobile phone in Laikipia has significantly improved social interactions and the sense of economic empowerment through fast and regular access to information among mobile phone users, this study also revealed some negative or unintended consequences of the mobile technology. People with no access to mobile phones may become socially isolated from the network of users to the detriment of their livelihoods. For example, the widespread use of money wallets, such as M-PESA platforms, in many areas in Laikipia to transact businesses or banking services means that people without mobile phones are probably excluded and economically or socially disempowered. To overcome these exclusions, many people who do not own a phone are reported to own a SIM card and borrow a phone when they need access to those services. This suggests that the rate of mobile

phone use is higher than the rate of phone ownership.

Our study identified that land ownership and rights influenced other issues of concern in Laikipia such as insecurity characterised by land activism and property damage, cattle rustling, human–wildlife conflicts, and the transmission of zoonotic diseases (Table 1). Our study also identified that these issues (insecurity, human–wildlife conflicts and animal disease transmission) as the most prominent and pressing for many residents, and the latter often share information about them and seek redress from the responsible agencies. Land in the area is regarded as an important factor of production from where other forms of livelihoods are derived. Most residents are thus preoccupied with these issues more often than with the TTBDs. Land ownership and rights directly influence the availability of, and access to, water and pasture for both humans and animals. Water and pasture are scarce natural resources in the area, and their scarcity affects the status and movement patterns of both wildlife and domestic animals, influencing security, human–wildlife conflicts, transmission of diseases and the social and political dynamics in the area (Bond, 2014a). The increasing human population in the area also exerts influence on land availability with consequences for socioeconomic activities. Water scarcity directly affects agricultural crop production, livestock husbandry, and wildlife conservation, with implications for the security of people, wildlife, and domestic animals (Bond, 2014b). Most pastoral communities have a strong economic and cultural attachment to livestock issues, and consequently they keep large herds of domestic animals comprising cows, goats, sheep, and camels for economic and cultural purposes (Bond, 2014a). Because of the scarcity and competition over these scarce resources such as water and pasture in semi-arid areas, large-scale movements of domestic animals and wildlife over a wide area are common in the dry season, sometimes resulting in massive loss of domestic animals to drought and conflicts with wildlife (Bond, 2014a; Wiesmann et al., 2000; Huho et al., 2011). To restock animals lost to drought, nomadic pastoralists may opt for cattle rustling (cultural practice) and private land invasion, further complicating land ownership and property rights issues, human–wildlife conflicts, and the spread of animal diseases. Our study corroborates with the findings of other studies in the area (e.g., Bond, 2014b, Wiesmann et al., 2000) that revealed that insecurity was influenced by competing claims over scarce natural resources such as water and pasture, leading to violent conflicts.

In this study, we found that, although at first sight it seemed that land ownership and land rights, insecurity, wildlife conflicts, and disease transmission were not related, a closer look at the dynamics of the issues revealed that they are in fact related, thereby complicating the TTBD problem and control in the area. For instance, insecurity because of land activism has become common during the dry season when pasture and water are exhausted in the pastoral areas. Illegal land invasions in the area are characterised by destruction of boundary fences, a common tool for demarcating land as proof of ownership, displacement of wildlife from their habitats into settlements or farming areas causing human–wildlife conflicts. Studies elsewhere in Africa such as in Sudan and Ethiopia, both in the East African region, with almost similar pastoral communities and practices, have also demonstrated a direct relationship between pastoral activities such as livestock movements and the spread of diseases, including (Dejene et al., 2016). The spread of these diseases has major ramifications for the wellbeing of many poor pastoral communities reliant on livestock for economic and cultural purposes (Gebremariam et al., 2013).

Our study shows that this has implications for stakeholder relationships and how information is communicated and shared. To entrench their activities, pastoral communities in Laikipia have formed groups for social networking, synonymous with political agency, for agitating for access to water and pasture from large-scale commercial and government-owned ranches. These social networks are maintained and organised using mobile phones, which are now commonly used as a mode of communication in the area. Pastoral farmers in Laikipia were

observed to use mobile phones for social networking, information sharing, purchase of farm inputs, and sale of livestock products, effectively empowering them. However, social media such as Facebook and WhatsApp can only be used by smart phone users, who tend to be mainly sedentary youth and more highly educated stakeholders who know how to operate those phones and have regular access to electricity. In particular, land invasion and property destruction were cited as sources of suspicion among stakeholders such as small-scale agro-pastoral farmers, large-scale commercial farmers, and security agencies, affecting their relationships. For example, immigrant pastoral communities from neighbouring counties use mobile phones to plan illegal invasions of private or community land and cattle rustling raids, effectively complicating security issues. This is a classic example of how mobile phones are used to share information in unanticipated ways. Governmental agencies such as the National Police Service, KWS, and livestock extension officers also use mobile phones to respond faster to their respective clientele and thus help improve response time and build synergies among them to address the problems. With mobile phone use in the area, the security situation has further deteriorated because of improved communication between land activists. Similar findings were observed in a study of the role of mobile phones and conflicts in Sudan and Mali (De Bruijn, 2009), where armed conflicts were planned and executed by warring parties using mobile phones.

5.2. Reflection on mobile phone usage and implications for citizen science (EVOCA)

The increasing use of mobile phones for various socioeconomic activities in Laikipia has important implications for the citizen science platform (EVOCA) that is envisioned to address the TTBD problem in the area. We therefore reflect on what we can expect from EVOCA's potential role in addressing TTBDs vis-à-vis other issues of concern. First, residents in Laikipia are faced with pressing issues such as insecurity, human–wildlife conflicts, and notifiable zoonotic diseases that influence what people communicate and share information about (Table 1). These pressing issues eclipse stakeholders' motivation to share information on TTBDs. Second, although our research illustrates that pastoral farmers have very effective networks for sharing information about issues of concern, including diseases, this study encountered little evidence of EVOCA's underlying assumption, namely, that the ineffective control of TTBDs is caused by imperfect information sharing and limited mobile phone connectivity, because people in the area have since time immemorial shared information using other traditional approaches and networks and mobile phone usage has only complimented – and even strengthened – the traditional social connectivity.

Institutional and policy issues linked to the stakeholders involved in the TTBD problem, such as those related to World Bank SAPs, policies that removed the subsidy for acaricides and decentralised livestock disease control from the government to farmers, have affected efforts to control TTBDs. For example, small-scale livestock farmers in the area were unable to effectively apply acaricides and other control interventions because of the prohibitive costs involved, demotivating farmers from effectively addressing the problem (Mugambi et al., 2012; Minjauw and McLeod, 2003). Conversely, large-scale commercial farmers in the area have adequate budgets to combat livestock diseases (Mizutani et al., 2012). This study therefore found insufficient information to support EVOCA's initial assumption that ineffective TTBD control in Laikipia is driven by imperfect information sharing issues.

This diagnostic study critically questions whose problem it is that the citizen science EVOCA on TTBDs in Kenya is trying to address. The central implication is that a citizen science platform in Laikipia can only be made to work if it aligns well with the pressing issues of concern, offers a motivation to share, and indicates how information collected would be used by all stakeholders. For instance, in several other studies on innovations platforms and projects (Hounkonnou et al., 2012; Röling

et al., 2004; Sinzogan et al., 2006) in West Africa's Benin Republic and Ghana (whose underlying assumptions were similar those of EVOCA's), it was anticipated that the innovation project was going to empower local farmers, but it was found from diagnostic studies that the project did not align well with the contemporary issues affecting them.

Here in Laikipia, residents voluntarily report on insecurity and human-wildlife conflict-related issues thanks to incentives such as payment of wildlife compensation claims by the government and prompt response from security agencies such as the National Police Service to emerging insecurity issues. The success of citizens reporting other issues of concern in the area suggests that EVOCA and citizen science for TTBDs have the necessary infrastructure that includes a high mobile phone adoption rate and the presence of stakeholders involved with the problem, but residents do not perceive the issue as a prominent problem. Consequently, local people's perception of the issue reduces their motivation to report about TTBDs.

We started out by questioning whether citizen science for development is a technology of humility or a technology of domination. We can now conclude that it is neither but that it has the potential to be both. The interest of researchers then is, of course, not in one of these states, but in the conditions that determine whether a citizen science initiative will become a technology of humility or a technology of domination. Citizen science for development provides a unique opportunity to supplement conventional scientific approaches and participation to create synergies to include even "amateur" scientists in the collection and dissemination of information to address a problem in an area (Roy et al., 2012; Silvertown, 2009), enhancing collaborations and building social networks to address development goals (Klerkx and Leeuwis, 2008b, a; Klerkx et al., 2012). In so doing, citizen science holds the promise of providing new insights that can help us successfully address the emerging challenges in different spheres of life in many areas. Despite all the necessary technological infrastructure in the area, including a high mobile phone adoption rate and the presence of various stakeholders, this study found insufficient grounds to demonstrate that lack of information sharing and mobile phone use may be leveraged to address the TTBD problem. The study also found that other pressing issues, including poor security, human-wildlife conflicts, and occurrences of notifiable diseases, eclipse the TTBD problem in the area. Therefore this study suggests that, to make citizen science work effectively and address the TTBD problem in Laikipia, it should address the local pressing issues – such as poor security, human-wildlife conflicts, and occurrences of notifiable diseases - that people communicate and report about using mobile phones.

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