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# Distribution of Livestock Ticks and Tick-Borne Pathogens, Hosts, Habitat and Diseases in Kenya and Some Parts of Africa: A Mini Review

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## Abstract

Livestock Ticks and Tick Borne Diseases (TTBDs) and associated secondary infections adversely impede the development of the livestock industry worldwide. The occurrence of TTBDs is determined by a myriad of factors including, availability of relevant hosts, anthropogenic activities, environmental conditions and climatic variabilities, which influence host accessibility, vector richness and pathogen acquisition and transmission in a natural mode. The current review therefore is focused on evaluating the distribution of tick species in Kenya and some parts of Africa and their associated hosts, pathogens, diseases and habitats as predicted by distribution model records in literature.

The review evaluated more than 61 tick species while presenting gaps in knowledge of some critical information that may undermine the expected predictive power of the distribution models for some of the tick species evaluated. For instance, some tick species did not have specific hosts and/or host-range, type of life cycle, geographic range, their pathogens lacked vector range, tick habitat, pathogens transmitted and disease (s) caused by the identified pathogens. Therefore, building a distribution model without such crucial information would be ineffective in its performance and not give the desired results. Distribution models should put into considerations the drastic changes in geographic ranges, whereby the old ranges could be diminishing and/or expanding while new ones are being exploited. This consideration shall have accumulative impact in developing practical frameworks for sustainable surveillance, control and management of TTBDs in endemic areas such as those of Africa. Existing predictive models need therefore continuous re-designing while putting into considerations emerging factors that determine the occurrence and distribution of TTBDs in order for the models to be relevant and serve the intended purposes.

**Keywords:** Epidemiology; Hosts; Kenya and Africa; Tick species; Tick-borne pathogens and diseases

## Introduction

Livestock Ticks and Tick-Borne Diseases (TTBDs) and associated secondary infections to various host animals and humans, present one of the worst devastating socio-economic problems facing humanity in the 21st century, worldwide [1]. Notwithstanding the intensive and extensive research on TTBDs for more than a century, TTBDs still remain the most problematic enemy and has continuously and adversely affected the livestock industry, wildlife, sports involving these animals and human health as well as economy in unprecedented way [2]. Many reasons have been advanced to explain this devastating epidemiologic incidence of TTBDs globally. This includes among other factors, the development of poor and unrealistic predictive models, initiation of donor based top down control programmes, erratic climate change challenges, resistance to acaricides, poor monitoring and evaluation programmes, encroachment to wildlife habitats, provision of poor veterinary healthcare services, ignorance of indigenous knowledge of the target community, etc., have thus affected hosts, vectors, pathogens and resulting TTBDs. The problem of TTBDs is particularly complex in Africa due to the complex diversity of tick species, numbering 650 species spread into over 13 different tick families. However, only a few of the 650 species are of socio-economic importance on the continent of Africa [3]. Variations in geographic ranges of the hosts, pathogens, vectors and that of anthropogenic activities coupled with unmatched climatic changes, have resulted into the outbreaks of ticks with the emergence of unique zoonotic diseases in both old and new geographical locations. To initiate a successful and sustainable preventive, control and management programmes of TTBDs, accurate and holistic epidemiological models need to be developed as well as a profound understanding of the distribution patterns of the hosts, vectors, pathogens and resulting diseases.

Globally models are very critical in the sustainable management of hosts, pathogens and vectors under any prevailing conditions and critically assist in decision making process as well as in surveillance and monitoring of TTBDs [4]. Therefore, care has to be taken that effective, efficient and reliable models are developed in order to achieve an eminent result of preventing, controlling and managing TTBDs.

The current review is focused on evaluating the distribution of tick species in Kenya and some parts of Africa and their associated hosts, pathogens, diseases and habitats as predicted by distribution models and some key factors influencing this distribution [5]. The overall question is how useful is this literature information in preventing, controlling and managing TTBDs in affected areas?

### Background of the problem

Data on the distribution of hosts, vectors, diseases, pathogens and associated environmental factors, weather/climate and anthropogenic activities is not well documented in Africa and even in Kenya albeit the devastating socio-economic effects of TTBDs on health, tourism, livestock and agricultural industries in particular [6]. The impacts of livestock tick vectors are further exacerbated by the fact that the existence of gaps, overlaps, difficulties in identifying new/potential habitats and contradictions in the previous and existing national, regional and continental distribution maps and databases are just too complex to be easily understood. In addition, factors determining the acquisition of new/potential habitats need to be clearly understood too in all contexts and under the prevailing circumstances so that useful and exhaustive predictive distribution models can be built to help in the strategic prevention, control and management of TTBDs. Therefore with such scanty and unrealistic geo-referenced information of data bases, it is not easy however, to develop a successful preventive, control and management programme, for either a country and/or region, hence, the continued socio-economic impacts of these vectors being felt in the world societies. More so, the emerging zoonotic and none zoonotic tick-borne diseases continue to threaten the livelihood of humanity and livestock as well as wildlife at an alarming rate. An eminent solution may not be forthcoming soon if models are developed without including all the existing complex factors that influence the dynamism of TTBDs [7].

## Literature Review

### Methodological approach of the review

A methodological approach used by Gachohi and co-workers was adopted. A search of peer-reviewed studies on TTBDs and TBDs in Kenya and Africa in particular was conducted from comprehensive databases including PubMed, Science Direct and CAB direct. The search was extended to available theses, conference proceedings, project reports etc [8]. Keywords were standardized across the databases to produce comparable searches and these were livestock ticks, distribution models, tick-borne diseases, epidemiology, prevalence, incidence, cattle, Kenya, Africa. References of all relevant articles were also searched to identify articles that could have been missed in the search. The search was conducted for all available years in each database. The keyword search produced articles published as of December 2021 and most relevant ones identified.

### Distribution of ticks and factors affecting their distribution

This manuscript represents a synthesis of knowledge on distribution of ticks under constant fluctuation and dynamic change of natural and human-engineered factors. If these factors are not holistically considered in a wider dimension when building tick distribution models, then the resultant models are not epidemiologically useful in the strategic prevention, control and management of TTBDs and associated zoonotic infections affecting humans, domestic animals and wildlife [9]. Ticks survive best with considerable diversity in tropical and sub-tropical lowland environments with combined factors of warm and more humid conditions with a blend of tree cover (such as savannah woodland) and grass coupled with suitable climatic and weather conditions. Geographical ranges with such combination of factors should be given a priority in terms of planning measures for prevention, control and management of TTBDs.

### Climate and weather factors

Global warming, a challenge to climate change is due to anthropogenic activities that result into tremendously increasing temperatures and altered patterns of precipitation and henceforth relative humidity thereby promoting the extension of the geographic ranges where conditions are favourable for survival of vector arthropods, the ticks, hosts and pathogens [10]. Climate change, which is majorly due to the emissions of greenhouse gases (such as carbon dioxide and methane) has had the ability to shift the geographic ranges of ticks a great deal, worldwide, thus engineering the emergence of new habitats, hosts, vectors, pathogens, diseases, unique clinical symptoms and complex resistant strains of vectors, hosts and pathogens. Further, it has been predicted that if the greenhouse gas emissions are not monitored and considerably reduced accordingly in the world, their effects on the planet, Earth will be disastrous and in my own view, humanity may not manage to sustain the challenges of these effects unless sustainable safety measures are put into considerations now [11]. The incidence of vector borne diseases such as Tick Borne Diseases (TBDs) have increased disproportionately in relationship to other emerging diseases and usually reach peak during severe weather incidences and climate anomalies. It therefore follows with logical necessity that climate and weather systems may restrict the established geographic ranges of existing tick populations while the global climate changes may provide new opportunities for the extension of ticks and other arthropods into previously unoccupied ecological zones. Climate and weather therefore influence a great deal the survival and the distribution of various tick species thereby determining the transmission cycles of tick-borne pathogens and henceforth the outbreaks and emergence of TTBDs [12].

### Temperature

Growth and development of ticks are almost temperature-dependent. Whether low or high temperatures, previous research has indicated that temperature as a factor in the natural world is able to reduce the survivalihood of tick species and further break the transmission cycle of pathogens in their respective geographical ranges. During studies of ticks in the field in Bungoma County, western Kenya, weather miss sharps such as prolonged drought, extreme cold, extreme heat, frequent floods and rainstorms, factors related to temperatures, had indeed deleterious effects of reducing the occurrence and abundance of ticks, thereby reducing the incidences of TTBDs. In other studies, it was noted that the brown dog tick, *Rhipicephalus sanguineus* can attack alternate hosts including humans more readily when ambient temperatures are high and can complete up to four generations a year and may become more important vectors of human disease as climate warms in its current range [13]. Although temperature was reported to be a poor predictor of annual nymphal blacklegged (*Ixodes scapularis Say*) tick abundance, it is a determining factor in the survival of ticks. For instance, previous studies have shown that low temperatures increases the mortality of ticks exposed to them. Previous studies have also shown that the questing activity of nymphal *I. scapularis* was reduced by high temperatures thereby reducing the infestation rate of the host animals.

## Relative Humidity (RH)

Just like in the case of temperature, the growth and development of ticks are almost relative humidity dependent [14]. Availability of moisture usually affected patterns of activity and abundance of *Ixodes scapularis* Say (blacklegged ticks) and therefore, Relative Humidity (RH), can be considered a determining factor in the survivalihood of these ticks, henceforth a useful factor in modelling. Low RH favours reduced survival of ticks. Therefore, warm and humid lowlands are considered the most suitable geographical ranges for tick abundance and endemicity of tick-borne diseases in Uganda.

## Rainfall

Variations in tick distribution is heavily influenced by rainfall amongst other climatic conditions and in turn, determines other factors such as temperature, relative humidity, vegetation and farming patterns. Precipitation has been found to affect the abundance of nymphal blacklegged (*Ixodes scapularis* Say) ticks [15].

## Host range and semiochemicals

Availability of hosts and host behavior are major determinants for the distribution of tick species. Ticks are evolutionary attracted to different host animals and guided to specific feeding sites in a complex push-pull mechanism involving repellent and attractant chemical cues [16]. Surprisingly, some of these semiochemicals are evolutionary known to originate from non-hosts, thus comprising of microbial agents occupying specific sites of the host.

## Habitat and vegetation cover

Availability of suitable habitat and vegetation are of prime importance for the maintenance and establishment of different tick species in their respective habitats. Identification and association of tick species and vegetation cover are critical in building useful tick distribution models that can predict risk areas for TTBDs for appropriate action to be taken. Tick species have different preferences in terms of hosts, habitat and environment they use in the course of their lifecycles. Ticks are usually found on woodlands, forests, meadows, savannah grasslands, bushes and even in semi-arid and arid environments. Ticks are occasionally found on various vegetation questing for a suitable host animal passing in the neighborhoods by extending its front legs well outstretched to hang in air and using them to technically grasp a host animal whenever it passes by Brenda, et al. Alternatively, some ticks hide in the environment utilized by their potential host animals and feed on them whenever the host animals come to rest. Vegetation density and levels of disturbance are also critical habitat variables affecting models that describe the distribution of ticks, as density of *Rhipicephalus appendiculatus* (brown ear tick) is known to increase with the extent of vegetation cover in its geographical range.

## Animal movement

This occurs during-trade, migratory birds, cattle rustling, roaming wildlife, sporting events involving animals, giving out animals as gifts, cultural ceremonies, nomadism, dowry payment, migration due to civil unrest etc. Ectoparasites like ticks, which remain attached to the host animals for quite some time, become transferred to new habitats during host movements [17]. So far, the distributions of *Rhipicephalus* (Boophilus) *microplus* and *Rhipicephalus sanguineus* have globally shown how humanity can facilitate the effective and efficient spread of ticks and probably other ectoparasite arthropods by the movement of domestic host animals. Although wildlife hosts may not account for much in terms of tick dispersal, particularly that involving thousands of miles away, migratory birds have been known to traverse continents with their bodies heavily infested with ticks, dropping them wherever they stop along the way. While roaming wildlife, some acting as reserviour hosts, together with trade play a significant role in tick dispersal. What is not known and clear is, whether or not the dispersed and dropped ticks find a suitable habitat, environment and appropriate hosts to enable them continual perpetuation of life.

## Sharing of habitats amongst humans, domestic animals and wildlife

Wildlife such as reptiles, mammals and birds, harbour a wide range of tick species on their bodies. Human encroachment on wildlife habitats enhances contact with ticks more particularly during hiking and/or camping. Also sharing of grazing grounds between domestic animals and wildlife and thereafter the domestic animals are brought in humans' homesteads where animals are housed together with animals resulting into an interaction that allows ticks to be transferred between humans and domestic and wild animals in unpredictable ways [18]. The wish to preserve natural vegetation to keep the environment beautiful in homesteads has attracted wildlife close to human dwellings thereby increasing contacts of ticks with humans.

## Poorly developed tick distribution models

Failure of distribution models to give useful and leading information on geographical location of various tick species, together with the associated hosts and tick-borne diseases. It is now clear that models without proper input of required information of influencing abiotic and biotic factors, cannot be useful predictor models of hosts, vectors, pathogens, environment and diseases. The spatial distribution models of tick vectors help establish a baseline for monitoring tick outbreaks and future spread of tick borne-diseases. Distribution modelling studies are urgently required in order to predict precisely any changes in tick occurrence as well as tick distribution with a view to detecting the occurrence of TTBDs with respect to changes in the climatic conditions.

## Host resistance to ticks and tick resistance to acaricides

These two types of resistance may function as regulatory mechanisms to the complexities surrounding tick lifecycles and transmission cycles that are heavily affected by climate change. The East Africa indigenous cattle are known to co-exist with TTBDs and ensure endemic stability of TBDs in most geographical ranges they occur thereby reducing greatly the overreliance to acaricides, which are environmentally unfriendly in all respects. Excessive and improper applications of acaricides results into the development of acaricide-resistant tick populations, which can easily cause an outbreak of ticks and henceforth TTBDs. Also excessive application of acaricides to indigenous resistant cattle leads to the loss of both resistance to ticks and enzootic stability to TBD. It is advisable therefore those livestock farmers together with researchers and other relevant stakeholders should work towards preserving enzootic stability amongst indigenous cattle or re-establish it through immunization against TBDs.

## Habitat modification

This is caused by climate change, increase in human and animal populations and anthropogenic activities. Increase in human and animal populations result in drastic changes in land-use patterns, which favour the establishment and expansion of ticks to new geographic ranges, more particularly at the urban/agricultural interface, thereby providing new habitats for highly adaptable wild hosts as well as new domestic animal hosts for ticks. Farming patterns engineered by humanity greatly influences tick distribution as it modifies the natural habitat.

## Increasing human population

This leads to constantly evolving land-use patterns in Kenya, especially in urban and peri-urban areas that impact on tick distribution. As human population increases, it increases the complexities of land-use patterns that usually affect the tick distribution.

## Breakdown of tick control programmes

This leads to tick outbreaks and in turn the outbreak of tick-borne diseases, which threaten cattle production in the absence of an effective tick control programme. Any disruption of intensive tick control regimens can have disastrous effects as was witnessed in Zimbabwe during the liberation civil war in 1980s when the breakdown of dipping programmes caused great socio-economic losses from TTBDs.

## Poor taxonomic tools for identifying tick species

Combination of morphological examination and molecular sequencing help in specific identity of tick species. Capacity building of the extension agricultural officers and livestock farmers on taxonomic tools for identifying tick species should be enhanced to improve monitoring and surveillance for ticks and TTBDs and as part and parcel of strategic tools for tick control measures.

## Lack of appropriate funding and research

This leads to failure to produce useful information for generating the desired tick distribution models. Poor funding has resulted in low prioritization during resource allocation and policy-making process. For instance research studies in Cameroon established that *Rhipicephalus microplus* had established itself well and was displacing the native, *Rhipicephalus* (Boophilus) species, such as R. *decoloratus*.

## Ignorance of the indigenous knowledge

Indigenous Knowledge is an important component in the strategic prevention, control and management of TTBDs in different geographical ranges. An effective tick control policy should put into account indigenous technical knowledge. Initiated conventional tick control programmes without a consideration of the indigenous knowledge of the target local and native people, always leads to failure.

# Discussion

## Effects of not putting into considerations the above factors

Inappropriate rise in the incidence and prevalence rates of tick species is most likely particularly in new geographic ranges. Therefore, extra effort is needed to emphasize the benefits of considering the above factors in particular when developing robust tick distribution models for monitoring and surveillance of ticks and TTBDs. If these factors are not critically considered, restoring and maintaining enzootic stability amongst indigenous cattle in order that the high costs of tick prevention, control and management are reduced, may not be forthcoming soon [19].

**N/B:** Information not available.

- Unidentified tick species collected from warthog in Ijara District in North Eastern province, Kenya.

- Unidentified *Hyalomma* spp. from cattle, goat (with *Bunyamwera* virus) and from sheep (with Bunyamwera virus) in Ijara district in North Eastern Province, Kenya.
- *Rickettsia felis* is the causative agent of flea-borne spotted fever, was detected in patients (who had previously associated with various vertebrate hosts) in Garissa Provincial Hospital, North Eastern province, Kenya with unspecified arthropod vectors (e.g., lice, fleas, ticks and mites). Rickettsiae are associated with arthropods for at least a part of their life cycle and are passed to other arthropods by transovarial transmission or horizontal transmission involving vertebrate hosts. Rickettsiae are small, gram-negative, fastidious bacteria of the α subdivision of Proteobacteria, which are frequently divided into 2 groups based on antigenicity, G+C content, culture conditions and actin polymerization: The typhus group including *Rickettsia prowazekii* and *R. typhi, t*he causative agents of louse-borne epidemic and flea-borne murine typhus and the spotted fever group including >20 species that may cause tick-, flea- and mite-borne rickettsioses.

### The tick and tick-borne models factor

The occurrence of Ticks and Tick Borne Diseases (TTBDs) is determined by a myriad of factors including, availability of relevant hosts, anthropogenic activities, environmental conditions, climatic variabilities, which vary a great deal, influencing host accessibility, vector richness and pathogen acquisition in a naturally framed and determined mode. This therefore implies that the distribution of TTBDs is never uniform and quite unpredictable in nature and henceforth, determining the socio-economic effects of TTBDs in any one given geographical region is not easy because of the multiplicity of complex factors involved. From the many studies conducted worldwide, over twenty-three different models developed to help in the assessment and management of TTBDs has not been fully fruitful due to the current socio-economic constraints still posed by TTBDs albeit a considerable sensitivity and specificity found in 20 models. The appropriate question would be, what is specifically lacking in the developed models that cannot make them achieve the intended results when these models are meant to provide sustainable preventive, control and management strategies that should improve the wellbeing of animals as well as that of humans from a socio-economic point of view? Do distribution models put into considerations the dynamic changes of geographic ranges of hosts, vectors, diseases and pathogens? Some key information could probably be missing and yet crucial in the development of the useful model [20]. With therefore continued escalating socio-economic costs due to TTBDs, these predictive models are increasingly becoming questionable. This therefore calls for concerted efforts amongst stakeholders to go back on the drawing board and re-design models based on their previous successes and failures.

## Conclusion

Worldwide, an explicit explanation about different forms of the distribution of ticks may not be exhaustive in a single sentence and/or in just a single reason but many conclusive remarks can, holistically be advanced in many different ways. Anthropogenic activities have been engineered both artificially and "de novo" with both catastrophic and beneficial changes to the environments that support the livelihood of ticks in many different ways. On the other hand, climate and weather systems may restrict the established geographic ranges of existing tick populations while the global climate changes may provide new opportunities for the extension of ticks and other arthropods into previously unoccupied ecological zones. Animal movement (such as those involving the importation of host animals, roaming of wildlife and bird migratory) and anthropogenic activities may account for, by far, the means by which the largest proportion of ticks spread in different habitats and on different host animals, while domestic animals provide the link of the chain of spread of ticks between humans and wildlife.

Modelling of ticks and tick-borne diseases is critical in the sustainable preventive, control and management framework of parasites, vectors, pathogens, hosts and environmental factors that support and enhance their livelihood. This is indeed crucial for it helps identify key targets with minimum costs on the environment as well as relevant hosts involved, thereby making sure that policy-makers make relevant decisions and that the implementing and the surveillance processes of the developed models are taking into account the appropriate and relevant measures that are by all means, sustainable. In view of the existence of over twenty-three different models developed in literature, the modelling development must therefore take the bottom-up approach in order that it takes into account capacity building at all levels to ensure awareness and sustainable continuity in generations. One purpose of this form of collaborative research is to shift decision-making process based on theoretical knowledge to the target local and/or native community, rather than conceding this role to the conventionally trained expert scientist who usually leaves the community at the end of the project.

Due to the interactions of hosts, vectors, diseases, pathogens, environmental factors, weather, climate and anthropogenic activities, there are drastic changes in geographic ranges, whereby the old ones could be diminishing and/or expanding while new ones are being exploited. The implication of these interactions and changes is that the new models under development must put into considerations these scenarios in order that they are useful and relevant and henceforth, serve the intended purpose. This consideration shall have accumulative impact in developing practical frameworks for sustainable surveillance, control and management of ticks and tick-borne diseases in endemic areas such as those of Africa.

This review has also indicated the absence of many relevant data sets, on hosts, vectors, diseases, pathogens, environmental factors, weather, climate, anthropogenic activities, previous and existing control mechanisms, which are critical in the development of any models and their absence therefore increases the predictive inefficiency of the developed models. To enhance the effectiveness of model development, enough funds should be set aside in order to conduct the state of the art research that can produce useful information for generating the desired tick distribution models. Nevertheless, a combination of different models may prove more beneficial by having a considerable performance predictive index, particularly in Africa where the distributions of parameters such as hosts, vectors, diseases, pathogens, environmental factors, weather, climate, anthropogenic activities etc, usually overlap.

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## Conflict of Interest

The author declares that there is no conflict of any interests regarding the publication of this manuscript in any ways.

## Declaration

Author declares that this manuscript is our own original research work and that have read and confirmed the content. Authors further confirm that the content of the manuscript has not been presented for publication in any other journal and in any other form of this nature and that all sources of materials used for the research have been fully acknowledged accordingly.

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