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## Driving forces for changes in geographic range of cattle ticks (Acari: Ixodidae) in Africa: A review

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### Abstract

Ticks are the most important external parasites of cattle and are known to transmit more pathogens than any other group of arthropods worldwide. About 80% of the world cattle population is at risk of ticks and tick-borne diseases, causing a global annual loss of \$US22–30 billion. In Africa, the impact of ticks is ranked high, and they transmit diseases such as cowdriosis, anaplasmosis, bovine babesiosis and theileriosis. A range expansion of ixodid ticks has been observed in Africa, in particular for the genera *Amblyomma* and *Rhipicephalus*, which contribute greatly to cattle loss owing to morbidity and mortality. Distributional changes in ticks can lead to the emergence or re-emergence of infectious and parasitic diseases. Climate change is frequently invoked as the primary cause of tick distribution, but it is not the only factor. Human lifestyle changes, including transportation of livestock within countries, have promoted the introduction of new tick species and the diseases they transmit. One such example is the spread of the Asian cattle tick *Rhipicephalus (Boophilus) microplus* to West Africa. *Rhipicephalus (Boophilus) microplus* was recorded for the first time in Namibia and was probably introduced into Namibia from South Africa. Likewise, *Amblyomma variegatum*, the vector of heartwater disease, has the largest distribution in Africa. Its spread is outside its native range and it is considered the second most invasive tick species after *R. (B.) microplus* on the continent. *Rhipicephalus (Boophilus) microplus* is a one-host tick that is reported to be resistant to conventional acaricides and this contributes largely to its spread into non-endemic areas.

**Keywords:** Acaricide resistance, climate change, epidemiology, range expansion, tick ecology

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### Introduction

Ticks are hematophagous acarines, which belong to the phylum Arthropoda, class Arachnid and order Acari (Walker *et al.*, 2003; Guglielmone *et al.*, 2010). They are regarded as one of the leading vectors of diseases of veterinary importance to the livestock industry globally (Jongejan & Uilenberg, 2004). Various studies have reported that ticks and tick-borne diseases (TTBDs) affect 80% of the world cattle population, particularly in tropical and subtropical countries (Ghosh *et al.*, 2006; Ahmed *et al.*, 2007; Marcelino *et al.*, 2012) and cause an estimated annual loss of US\$22–30 billion (Lew-Tabor & Rodriguez Valle, 2016). Four groups of tick-borne diseases TBDs that pose major constraints to cattle production and are of veterinary importance are cowdriosis (heartwater), anaplasmosis (gall sickness), bovine babesiosis (redwater) and theileriosis (Marcelino *et al.*, 2012). Ticks affect domestic animals directly with non-specific symptoms such as anaemia, restlessness, dermatosis, toxicosis, paralysis, loss of condition and decrease in milk production (Jonsson, 2006).

The economically most important ixodid ticks of livestock in tropical regions belong to the genera of *Amblyomma*, *Hyalomma* and *Rhipicephalus*, including subgenus *Boophilus* (Frans, 2000). In Africa, *A. hebraeum* and *A. variegatum* are the vectors of *Ehrlichia (Cowdria) ruminantium*, which are the causative

organisms of heartwater in cattle, sheep and goats. *R. (B.) decoloratus*, the African blue tick, is the vector of *Babesia bigemina* and *Anaplasma marginale*, while *R. (B.) microplus*, the Asiatic blue tick, is the vector of *B. bovis*, *B. bigemina* and *A. marginale*, the causative organisms of redwater and gall sickness in cattle. *Rhipicephalus appendiculatus*, the brown ear tick, transmits several species of *Theileria*, causing theilerioses in cattle (Norval & Horak 2004; Madder *et al.*, 2011). *Amblyomma variegatum* is established in several regions in Africa and is regarded as the second most invasive tick species after *R. (B.) microplus* (Barré & Uilenberg, 2010). In Zimbabwe, *A. variegatum* is colonizing territories in which it was not found previously (Estrada-Peña *et al.*, 2008; Sungirai *et al.*, 2015). However, numerous studies have shown that cattle with smooth light-coloured short-hair coats (Nguni and Boran breeds) tend to have lower tick infestations than those with rough darker-coloured long-hair coats (Martinez *et al.*, 2006; Muchenje *et al.*, 2008; Katiyatiya *et al.*, 2014). Recent studies have shown that Nguni cattle carry lower tick loads (Marufu *et al.*, 2011; Nyangiwe *et al.*, 2011) and therefore seem to be more resistant to ticks than Angus and Bonsmara cattle (Muchenje *et al.*, 2008). Recently, the resistance phenotype has been linked to a delayed hypersensitivity reaction in the Nguni breed (Marufu *et al.*, 2013) confirming the observations of Constantinoiu *et al.* (2010) of Holstein Friesian (a susceptible breed) and Brahman (a resistant breed) cattle.

The direct effects of ticks on their hosts include tick toxicosis, metabolic disturbances, anaemia and tick worry. All these factors can lead to production losses or deaths (Bazarusanga *et al.*, 2007). Losses because of tick infestations can be substantial and are known to be breed-dependent with *Bos indicus* cattle being more resistant than *B. taurus* breeds. However, resistance can be improved through selection (Frisch, 1999; Porto Neto *et al.*, 2011). Few studies have reported on the costs involved in tick control and the diseases they transmit, but earlier reports were in the region of US\$8.43 for plunge dipping, US\$13.62 for hand spraying and US\$21.09 for pour-on treatments per animal per year (De Castro, 1997; D'Haese *et al.*, 1999). According to Jonsson *et al.* (2008), losses that can be directly ascribed to TBDs are morbidity, mortality and costs of veterinary services, including vaccines and treatment of sick animals. In Africa, losses due to TTBDs were estimated to be US\$160 million (Dold & Cocks, 2001). As well as the large numbers of tick-related cattle deaths, over 30% of calf crop was reported to be lost because of TBDs in Uganda (Vudriko *et al.*, 2016). Tick control is a global problem and is therefore a priority for many countries (Lodos *et al.*, 2000). Control of tick infestations rests overwhelmingly on the use of conventional acaricides, although the disadvantages are recognised. A broad range of acaricides – including arsenical chlorinated hydrocarbons, organophosphates, carbamates, formamidines and synthetic pyrethroids – is being used to control ticks on livestock (Rajput *et al.*, 2006; Spickett, 2013). If chemical acaricides are applied correctly, they are efficient and can be cost effective (Willadsen, 2006). In South Africa, like the rest of African countries, indigenous breeds such as Nguni are recommended for use in the integrated control of ticks (Mapiye *et al.*, 2009; Marufu *et al.*, 2011).

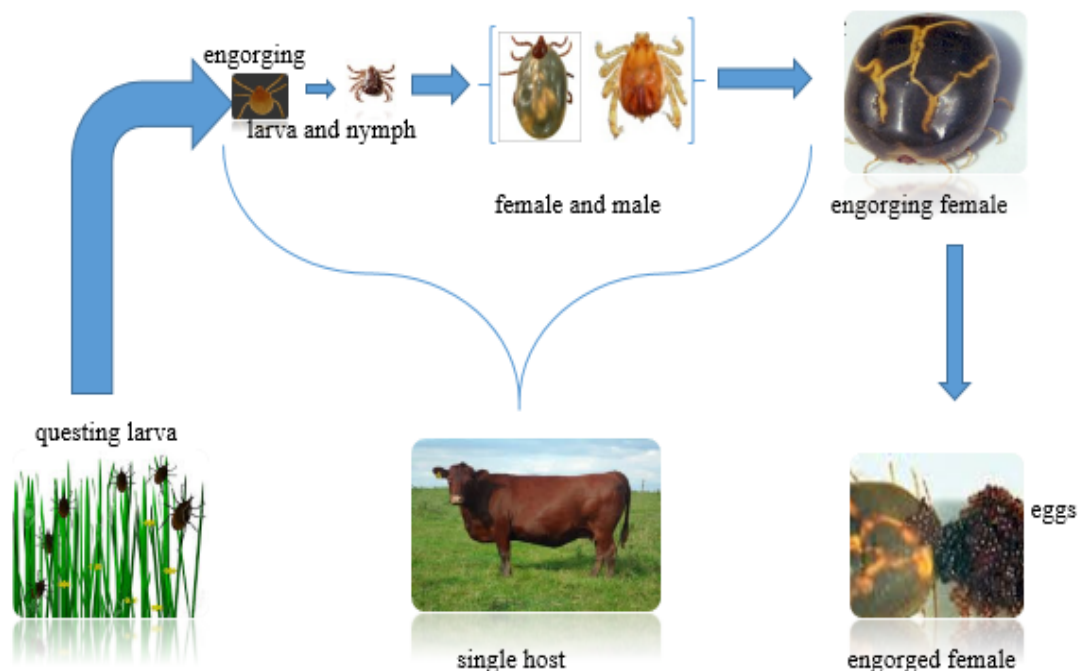
Chemical control of ticks using acaricides is often accompanied by serious drawbacks, including chemical residues in food (meat and milk products), environmental contamination, selection of acaricide-resistant ticks, the expense of developing new acaricides and the difficulty of producing tick-resistant cattle while maintaining desirable production characteristics (Miller *et al.*, 2005; Aguilar-Tipacamu *et al.*, 2011; Abbas *et al.*, 2014; Vudriko *et al.*, 2016). Tick control using acaricides was viewed as one of the best methods, but it has been shown recently that ticks have developed resistance to a range of acaricides (Rajput *et al.*, 2006). Although most reports of resistance are for *Rhipicephalus (Boophilus)* spp., acaricide-resistant multihost ticks have been reported (Frisch, 1999). Despite the acaricide-resistance phenomenon, there has been a steady increase in the abundance and spatial distribution of economically important ticks (Sutherst, 2001; Süß *et al.*, 2008).

The issue of climate change is a controversial debate, but from the perspective of the climate change, ticks are affected mostly because of their strong dependence on living and non-living conditions for local survival and reproduction. Climatic factors such as temperature and rainfall vary, thus corresponding changes in tick phenology, survival and development have been observed (Lindgren & Jaenson, 2006; Gray, 2008; Ogden *et al.*, 2008; Léger *et al.*, 2013). Estrada-Peña & De la Fuente (2014) refers to tick phenology as tick lifecycle events and explain how these are influenced by seasonal and inter-annual variations in weather. Tick lifecycles, in particular the larval stage, undergo specific intense interactions at the host interface, such as physiological and immunological defences. Although climate change may have huge or little impact on the spread of ticks and the associated pathogens they transmit, farmers perceive that the rapid spread of TTBDs is probably the result of transhumance (Adakal *et al.*, 2013; Kamani *et al.*, 2017; Nyangiwe *et al.*, 2017). In this review article, the distribution of ticks of veterinary importance in Africa and their epidemiological implications are discussed.

## Tick biology and ecology

Ticks (Acarina: Ixodoidea) are divided into three families, namely Argasidae or soft-bodied ticks (191 species), Ixodidae or hard ticks (701) and Nuttalliellidae, which consists of only one species, *Nuttalliella Namaqua* (Guglielmo *et al.*, 2010; Estrada-Peña & De la Fuente, 2014). This review focus on the Ixodidae family, which affect the cattle industry most. About six important genera of ixodid ticks are found in Africa, including subgenus *Boophilus*. These are *Amblyomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes* and *Rhipicephalus* (*Boophilus*) (Jongejan & Uilenberg, 2004). There are four stages in the lifecycle of an ixodid tick, namely egg, larva, nymph and adult. Unlike the argasid ticks, which mate off-host in the vegetation, ixodid ticks copulate while on their host (Horak *et al.*, 2002). The engorged female drops to the ground and lay eggs in the soil. After three to four weeks, six-legged larvae hatch from batches of approximately 20 000 eggs from the genus *Amblyomma* and approximately 3000 eggs from the genus *Rhipicephalus*, including subgenus (*Boophilus*). Larvae can take three to five days to fully engorge with blood, nymphs take four to eight days and females five to 20 days. When the ticks have engorged with blood, they detach from the host's skin and drop to the ground. Males of most types of ticks feed, but do not expand like the females (Latif & Walker, 2004). For survival, each of the post-embryonic stages requires a blood meal.

Ixodid ticks undergo one-host, two-host or three-host lifecycles (Walker *et al.*, 2003). In the one-host lifecycle, ticks remain on the same host for the larva, nymph and adult stages, leaving the host only prior to laying eggs (Figure 1). The two-host lifecycle is similar, but only the larvae and nymphs feed on the same host and the adults feed on another host. Eggs are laid in the physical environment. The second host may be the same individual as the first host, the same species, and even a second species. Three-host ticks require three animals to enable them to complete their lifecycle, because each of the two immature stages drops from the host after feeding, and moults to the next stage, with the adults feeding on a third host (Figure 2). Most ixodid ticks belong to this group, for example *A. hebraeum* and *R. appendiculatus*. The three hosts are not always the same species, but may be the same species or even the same individual, depending on host availability for the tick (Latif & Walker, 2004).

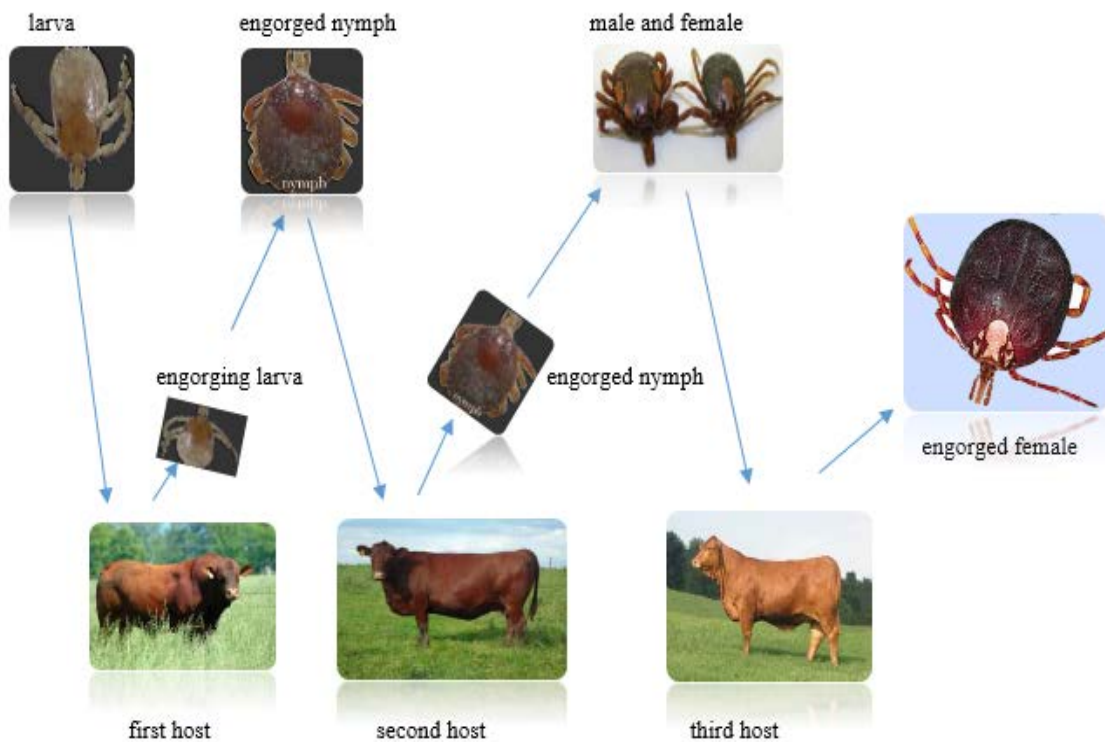


**Figure 1** Lifecycle of the one-host tick

The lifecycle of one-host ticks is usually rapid. For sub-genus *Boophilus* it takes three weeks for feedings on one host and two months for egg laying and hatching of larvae. This lifecycle has been modified from Walker *et al.* (2003).

For ticks to transmit diseases, they must be acquired from an infected host, passed into the next active stage, then successfully transmitted into a new host (Kahl *et al.*, 2002; Estrada-Peña *et al.*, 2013). At each blood meal, ticks can become integrated into the epidemiological chain of pathogen transmission by transstadial (stage to stage or horizontal transmission) or transovarial (female to egg, or vertical transmission) passage (Kahl *et al.*, 2002; Estrada-Peña & De la Fuente, 2014). Walker *et al.* (2003) define transovarial transmission as that which occurs when a microorganism is transmitted from one vertebrate host to another by infecting a female vector, then passing it through the eggs to the larvae. Transstadial transmission occurs when a microorganism is transmitted between vertebrate hosts by infecting one stage of the vector, then passing to the next stage of the lifecycle of the vector during moulting. When the next stage feeds, the microorganism passes to another host (Walker *et al.*, 2003). However, transovarial transmission of *Babesia* spp. has been demonstrated for species of ticks such as *R. (B.) microplus* and *R. (B.) decoloratus*. Of the species that affect cattle, *B. bovis* and *B. bigemina* are the most economically important worldwide (Bock *et al.*, 2004; World Organization for Animal Health (OIE), 2008; Terkawi *et al.*, 2011).

For the first time Socolovschi *et al.* (2007) demonstrated transstadial and transovarial transmission of *Rickettsia africae* in naturally infected *A. variegatum*. *Rickettsia africae* is the causative agent of African tick bite fever, which is transmitted by hard ticks of the *Amblyomma* genus (Jensenius *et al.*, 2003). *A. hebraeum*, a tick found in large ruminants and wildlife species, is the most common vector of *R. africae* in southern Africa. Epidemiological evidence indicates that *A. variegatum* is the predominant vector for the rest of sub-Saharan Africa and the West Indies (Jensenius *et al.*, 2003; Socolovschi *et al.*, 2007). Cattle, wild game and other ungulates are the principal hosts of the *Amblyomma* vectors, although larvae and nymphs may also parasitize birds and rodents.



**Figure 2** Lifecycle of the three-host tick.

The lifecycle of three-host ticks is slow, and takes from six months to several years to complete (modified from Walker *et al.*, 2003).

A tick's habitat is composed of the variety of biotic and abiotic conditions in which it is found. Ticks are adapted to two contrasting components of their habitat, namely the physical environment and their host (Walker *et al.*, 2003). Three-host ticks (such as *A. hebraeum*) spend up to 99% of their lives off the host (Oliver, 1989; Pfäffle *et al.*, 2013). Ixodid ticks find their hosts by 'questing' on vegetation or by moving near to distant stimuli (Pfäffle *et al.*, 2013). Estrada-Peña *et al.* (2013) define 'questing' as the process in the lifecycle in which active stages search for the host. This behaviour of seeking for the host is influenced by

micro- and macroclimatic factors such as temperature and rainfall (Knap *et al.*, 2009). Various studies have confirmed that the developmental stage (moulting) and questing activity of ticks are controlled by climate (Randolph *et al.*, 2002; Perret *et al.*, 2004; Estrada-Peña & Venzal, 2007). It is known that temperature regulates the developmental rates. For example, in winter, low temperatures inhibit fast development until temperatures rise in the spring (Estrada-Peña & De la Fuente, 2014). In summer, long periods of high temperatures can promote mortalities of moulting or questing stages. However, large numbers of free-living ticks appear on the vegetation in spring in temperate regions as a consequence of the synchronous hatching of larvae, driven by the rise in temperature after the winter season. This was shown by Nyangiwe *et al.* (2011) in the province of Eastern Cape, South Africa. They reported large numbers of *R. (B.) microplus* larvae on the vegetation in spring, which outcompeted those of the native tick *R. (B.) decoloratus* in the study area. The temperature, humidity, host availability and vegetation play a pivotal role in the regulation of the tick lifecycle. The types of vegetation in which cattle graze influence the infestation rate of ticks (Marufu *et al.*, 2011).

### **Acaricide resistance in *Rhipicephalus (Boophilus) microplus* cattle ticks**

Several studies have reported the resistance of ticks to synthetic acaricides, particularly organophosphate, synthetic pyrethroids and formamidines (amitraz) in the regions in which the cattle tick *R. (B.) microplus* is found (Soberanes-Céspedes *et al.*, 2002; Miller *et al.*, 2005; Alonso-Díaz *et al.*, 2006; Ntondini *et al.*, 2008; Guerrero *et al.*, 2012; Reck *et al.*, 2014; Van Wyk *et al.*, 2016; Vudriko *et al.*, 2016). Ticks of the sub-genus *Rhipicephalus (Boophilus)* are most frequently associated with selection for resistance to acaricides, particularly *R. (B.) decoloratus* and *R. (B.) microplus*. Unlike the native tick *R. (B.) decoloratus*, which infests cattle, goats, horses, impalas, bushbuck, kudus, zebras, *R. (B.) microplus* is most affected since it is strictly a parasite of cattle and is usually found on other host species if they graze with cattle (Nyangiwe *et al.*, 2013a).

The southern cattle tick *R. (B.) microplus* is a highly adaptable ectoparasite that has become established in nearly all tropical and subtropical regions of the world in which cattle production occurs (Bram *et al.*, 2002; Busch *et al.*, 2014). It is exposed to every application of acaricide, thus promoting the rapidity with which selection for resistance can take place. The resistance of *R. (B.) microplus* to chemical acaricide plays a role to its spread into non-endemic areas (Awa *et al.*, 2015). The rapid spread of *R. (B.) microplus* in South Africa (Tønnesen *et al.*, 2004; Horak *et al.*, 2009; Nyangiwe *et al.*, 2013a; Nyangiwe *et al.*, 2017), Tanzania (Lynen *et al.*, 2008), Zimbabwe (Smeenk *et al.*, 2000; Sungirai *et al.*, 2015) and West Africa (Madder *et al.*, 2007, 2012; Adakal *et al.*, 2013) is one such example. Recently, farmers encountered tick resistance to the use of acaricide in Burkina Faso, Mali and Togo. This resulted in the alarming spread of *R. (B.) microplus* soon after its first discovery in Ivory Coast and Benin (De Clerq *et al.*, 2012; Madder *et al.*, 2012; Adakal *et al.*, 2013). In South Africa, Nyangiwe *et al.* (2013b) reported on the first record of *R. (B.) microplus* in Namibia. Of the 18 farms surveyed in Namibia, four were positive for *R. (B.) microplus*. The farmers stated that they had bought bulls from South Africa for herd improvement. *R. (B.) microplus* is resistant to multitudes of chemical compounds. This is great concern for its rapid spread. To solve resistance problems, it is necessary to consider alternatives for efficient and safe control of ticks. The use of resistant breeds is an important means of tick control in some countries, although dipping is still required to minimize tick loads.

### **Climate change, human driving forces, and tick distribution**

Various studies have reported on the issues of global change, climate change, tick distribution and re-emergence of TBDs, in particular for *Ixodes ricinus*, which is Europe's main vector of *Borrelia burgdorferi* sensu lato, the causative agent of Lyme borreliosis in humans (Guernier *et al.*, 2004; Gray *et al.*, 2009; Keesing *et al.*, 2010; Ogden *et al.*, 2013; Estrada-Peña & De la Fuente, 2014; Granter *et al.*, 2014; Medlock & Leach, 2015). Current global changes (for example climate change, deforestation, changes in land use, urbanization, increased trade and travel) affect the cattle industry worldwide, favouring the introduction of ticks and the diseases they transmit into previously free areas (Dantas-Torres, 2015; Kamani *et al.*, 2017; Nyangiwe *et al.*, 2017; Tabor *et al.*, 2017). However, tick species that transmit harmful pathogens in their native ranges seem likely to do the same in new establishments. Tick distributions are known to vary owing to interaction of many aspects, including climatic factors such as temperature and rainfall (Allen *et al.*, 2002; Cumming & Van Vuuren, 2006). Over the last century, precipitation has risen by roughly 1% globally and the trend for maximum temperatures shows an increase of 0.88 °C, with minimum temperatures estimated to rise to 1.86 °C per 100 years (Githeko *et al.*, 2000; Khasnis & Nettleman, 2005; Intergovernmental Panel on Climate Change (IPCC), 2007; Pfäffle *et al.*, 2013). Temperature alone affects the reproduction and survival rates of tick species directly, in particular the larvae, which require specific conditions, including humidity (Vassallo *et al.*, 2000; IPCC, 2001; Estrada-Peña *et al.*, 2004). The tropical African climate is favourable to



most major vector-borne disease, including TBDs (Githeko *et al.*, 2000). It is estimated that in the Sahara and semi-arid parts of southern Africa temperatures may rise by 1.6 °C, but equatorial countries such as Cameroon, Kenya and Uganda could experience an increase of 1.4 °C by 2050 (Githeko *et al.*, 2000). Using a simple climate envelope model and a division of atmospheric research limited-area model (DARLAM), Olwoch *et al.* (2007) predicted the suitability of present and future climates for the distribution of 30 tick species under the genus *Rhipicephalus* in Africa. Their findings showed that East Africa and South Africa were the regions that were most at risk of climate-induced changes in tick distribution and TBDs and that more than 50% of the species they examined showed potential range expansion. However, climate is not always the only factor to consider when investigating the potential drivers of the spread of ticks in a particular region.

Changes in human habitation and settlement patterns, wide-scale movement of humans and the increased transportation of livestock contribute largely to tick distribution and to the pathogens they transmit (Fayer, 2000; Sutherst, 2001; Weiss, 2008; Barré & Uilenberg, 2010; Pisanu *et al.*, 2010.). Recently TBDs such as bovine babesiosis and anaplasmosis were observed in countries in which they were previously absent (Beugnet & Marié, 2009; Léger *et al.*, 2013). Using morphological and molecular identification keys, Kamani *et al.* (2017) confirmed the invasive tick *R. (B.) microplus* in two states in the south-western region of Nigeria, which shares international borders with Benin. In Benin, the spread of *R. (B.) microplus* has been reported (Madder *et al.*, 2012; De Clercq *et al.*, 2012). Owing to unrestricted movement of livestock for grazing or trade across Nigerian international borders, the introduction of *R. (B.) microplus* is predicted (Kamani *et al.*, 2017). Similarly, *A. variegatum*, a three-host tick that originated in Africa, was transported to Madagascar, Mascarene Islands and the West Indies at the time of the Atlantic triangular trade. Not only human driving forces contribute to the spread of *A. variegatum*, but the migratory population of cattle egrets (*Bubulcus ibis*) between the islands complicate the matter as they are the hosts for immature stages of this three-host tick (Pegram *et al.*, 2004; Barré & Uilenberg, 2010; Estrada-Peña & Salman, 2013). However, it is difficult to exercise adequate control measures for multi-host ticks owing to the number of hosts on which they feed and their invasive nature.

Distributional changes in ticks are major concerns in tropical and subtropical regions. However, tick distribution is often accompanied by the displacement of native tick species by the invasive species. The invasions of *R. (B.) microplus* in New Caledonia, West Africa, South Africa and Namibia and of *A. variegatum* in the Caribbean through livestock transportation are perfect examples (Madder *et al.*, 2012; Léger *et al.*, 2013; Nyangiwe *et al.*, 2013b; Kamani *et al.*, 2017; Nyangiwe *et al.*, 2017). *Rhipicephalus (Boophilus) decoloratus* is indigenous and widespread on the African continent (Figure 3), whereas *R. (B.) microplus*, a parasite of bovid species, was introduced to South Africa by cattle that were imported from Madagascar after the rinderpest epidemic in 1896 (Spickett *et al.*, 2011; Estrada-Peña & Salman, 2013). In South Africa, several reports have confirmed the displacement of *R. (B.) decoloratus* by *R. (B.) microplus*. It appears that the spread of *R. (B.) microplus* is advancing more quickly than during the previous 100 years where the *R. (B.) decoloratus* was the most abundant tick species (Tønnesen *et al.*, 2004; Horak *et al.*, 2009; Nyangiwe *et al.*, 2013a; Nyangiwe *et al.*, 2017). However, a viable *R. (B.) decoloratus* / *R. (B.) microplus* hybrid exists. This was confirmed by two studies in the Eastern Cape in South Africa (Nyangiwe *et al.*, 2013a; Nyangiwe *et al.*, 2017). The slightly shorter lifecycle of *R. (B.) microplus*, and the presence of its larvae on vegetation in winter in the eastern region of the Eastern Cape, while those of *R. (B.) decoloratus* almost disappear (Nyangiwe *et al.*, 2011), may result in *R. (B.) microplus* completing one more lifecycle per year than *R. (B.) decoloratus*. This appears to enhance its chances of displacing *R. (B.) decoloratus* (Nyangiwe *et al.*, 2013a). However, *R. (B.) microplus* is advancing more quickly in Africa, and its distribution (Figure 4) is accompanied by outbreaks of Asiatic redwater in regions in which only African redwater had been recorded in the past (Madder *et al.*, 2012; Estrada-Peña & Salman, 2013).

In South Africa, *R. (B.) microplus* was recently introduced in the Northern Cape, where Nyangiwe *et al.* (2017) collected it for the first time in eight of 18 localities. In the Free State province, the tick was recorded for the fourth time, the first being from gemsbok in the north-west of the province (Tonetti *et al.*, 2009), the second from cattle in the north-east (Spickett, 2013), the third from four cattle and a single larva from a drag-sample (Horak *et al.*, 2015) and the fourth at one locality in Heilbron (Nyangiwe *et al.* 2017). The tropical bont tick *A. variegatum* has wider distribution in Africa than the native tick *A. haebraeum* (Figure 5).

*Amblyomma hebraeum*, commonly known as the South African bont tick, is native to southern Africa (Figure 5). Like other ticks of the genus *Amblyomma*, the tropical bont tick transmits heartwater, a fatal disease caused by *Ehrlichia ruminantium* and *R. africae*, the causative organism of African tick-bite fever (Léger *et al.*, 2013). *Amblyomma variegatum* is prevalent in more than 30 African countries and has been considered a serious danger to the US cattle industry because it could spread from the Caribbean to the coast of Florida (Barré & Uilenberg, 2010; Estrada-Peña & Salman, 2013). This tick has been reported to withstand long periods of time while waiting for a favourable host, namely approximately 20 months for an

unfed female. Once fed, she can lay about 20 000 eggs (Barré & Garris, 1990; Léger *et al.*, 2013). In addition, *A. variegatum* inhabits a diversity of habitats, from grassy steppes and mountain meadows to wet savannas. This ubiquity, together with its biology, has facilitated its spread outside its native range of Africa (Estrada-Peña *et al.*, 2007). It has colonized several zones from its native range, such as Caribbean, Madagascar, Comoro and Mascarene Islands and Yemen (Barré & Uilenberg, 2010). However, *A. variegatum* is now considered the second most invasive tick species after *R. (B.) microplus* (Barré & Uilenberg, 2010).



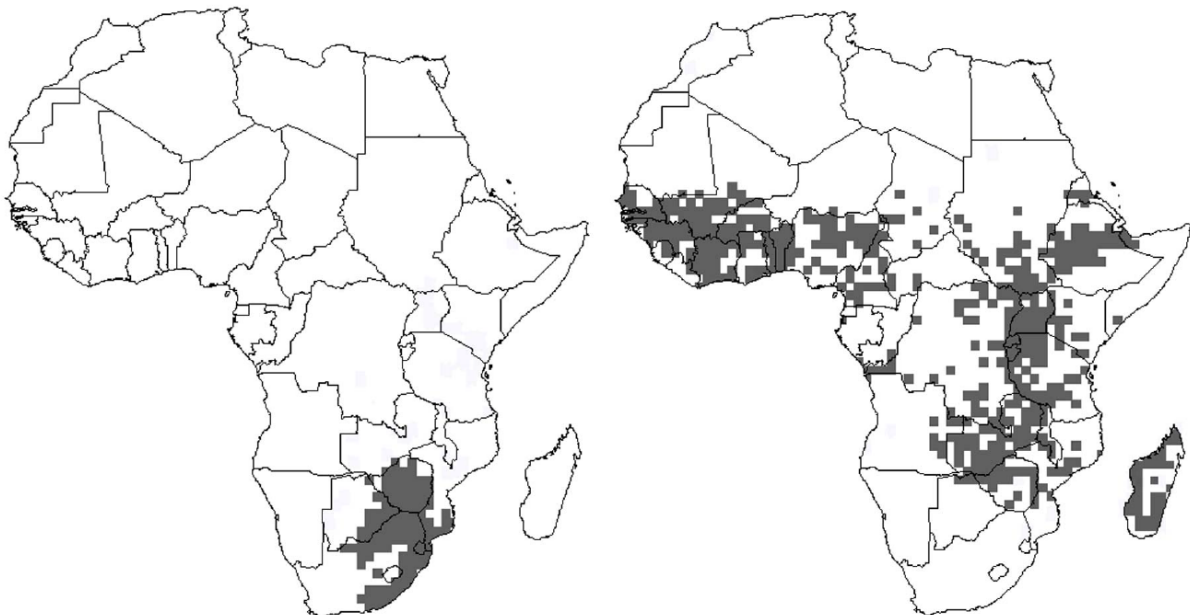
**Figure 3** Geographic range of the indigenous tick *Rhipicephalus (Boophilus) decoloratus* in Africa. (Source: Walker *et al.*, 2003)

Despite its spread, it is being displaced in many localities by the invasive tick *R. (B.) microplus*.

Concerns about the further spread of ticks to the continent have arisen from modelling the preferred climate niche of the tick (Estrada-Peña *et al.*, 2007). *A. variegatum* is adapted to a wide range of climatic conditions in its native distribution range (Beati *et al.*, 2012). Large cattle egrets are reported to compound its spread, in particular between the islands (Pegram *et al.*, 2004). Tick control for tropical cattle ticks has always been difficult, with accompanying acaricide resistance, but little attention has been paid to the huge potential of medicinal plants with acaricidal properties that are locally available (Mondal *et al.*, 2013). On the other hand, Mapholi *et al.* (2014) have suggested a genomics approach towards tick control using a single-nucleotide polymorphism (SNP). Genomic selection using SNP markers is regarded as a powerful new tool for genetic selection, which could assist farmers in making decisions on host genetic resistance to ticks (HGRT). However, to control livestock diseases by exploiting genetic information, in-depth knowledge of genome variations is required (Ibeagha-Awemu *et al.*, 2008; Mapholi *et al.*, 2014; Mapholi *et al.*, 2016).



**Figure 4** Geographic range of the invasive cattle tick *Rhipicephalus (Boophilus) microplus* in Africa, with recent observations (red cycle) of the tick in West Africa, Namibia and South Africa. (Source: Adakal *et al.*, 2017, Nyangiwe *et al.*, 2013b, Nyangiwe *et al.*, 2017)



**Figure 5** Geographic range of *Amblyomma hebraeum* (left) and *Amblyomma variegatum* (right) in Africa. (Source: Walker *et al.*, 2003)

For the epidemiology of heartwater disease and identification of the vector, these ticks occur together only in Zimbabwe.

## Conclusions

Climate change is central to the spread and establishment of new tick species in non-endemic areas. Such establishments promote an increase in tick densities and spatial range, which can lead to higher



prevalence of TBDs. In tandem with climatic factors, large-scale movements of humans and their animals play a role in speeding up the introduction of novel tick species and the diseases they transmit. Of the two tropical cattle tick species, *R. (B.) microplus* has the propensity to express acaricide resistance, which may contribute to the rapid spread of this species. On the other hand, *A. variegatum* is driven more by transhumance, climate trends and unpredictable movements of cattle egrets than by acaricide resistance. However, more awareness campaigns about the risks of transporting animals from native areas to new territories are required. This could be achieved if government implemented regulations that would avoid unrestricted cattle movement from one region to another and emphasize the involvement of veterinary services for animal transfer.

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#### Authors' Contributions

All the authors contributed from the onset of the manuscript and approve of the final version.

#### Conflict of Interest Declaration

The authors have no conflict of interest to declare.

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