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An overview of factors responsible for geographic distribution pattern of ixodid ticks in the Sudan

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Abstract

Tick fauna in the Sudan comprises over 70 species prevalent in diverse ecological zones. Among these are the most economically important ticks in Africa, namely *Rhipicephalus appendiculatus, Hyalomma anatolicum, Amblyomma variegatum, Amblyomma lepidum, Rhipicephalus (Boophilus) decoloratus* and *Rhipicephalus (Boophilus) annulatus.* Several factors determine the dynamic changes of tick distribution in the Sudan. These are animal movement either for trade, nomadism, or migration due to civil unrest etc., habitat modification such as deforestation, large-scale mechanized cultivation and urbanization; drought and desertification, and global climate change. The accelerated change in tick distribution results in outbreaks of several tick-borne diseases. Examples of these are East Coast fever, tropical theileriosis, malignant ovine theileriosis, heartwater and babesiosis by *Babesia bovis*. Emergence of these diseases in districts believed to be free is alarming and has adverse effects in the process of animal resources development. This communication discusses distribution patterns of the economically important livestock ticks in the Sudan and identifies new zones where ticks have established and the possible factors determining such distribution.

Keywords: Distribution, Factors, Livestock, Sudan, Ticks.

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Introduction

The Sudan occupies an area of one million square miles, extending from 4–22^{o}N of latitude and 22–38^{o}E of longitude, bordering on nine African countries namely Egypt, Libya, Chad, Central African Republic, Democratic Republic of Congo, Uganda, Kenya, Ethiopia and Eretria. It consists on the north-south direction of desert, semi-desert and Savannah of unique floral and faunal set up with five identified ecological zones of rainfall. Animal resources contribution in the gross domestic product (GDP) is estimated at about 20%. Livestock population accounts for 30 million cattle, 37 million sheep, 33 million goats and 3 million camels. About 39% of these are kept in the western Sudan, 27% in the southern, 24% in the central and 10% in the eastern and northern Sudan. About 80% of livestock population is owned by the traditional sector, namely nomads.

Tick fauna in the country comprises of over 70 species prevalent in diverse ecological zones. Among these are the most economically important ticks in Africa, namely *Rhipicephalus appendiculatus, Hyalomma anatolicum, Amblyomma variegatum, A. lepidum, Rhipicephalus (Boophilus) decoloratus* and *R. (B) annulatus.* These tick species are of veterinary importance in the Sudan. *R. appendiculatus* is the main vector of East Coast fever which is responsible for high mortalities of cattle in Southern Sudan (FAO, 1983). Similarly, *H. anatolicum*, the vector of tropical theileriosis and malignant ovine theileriosis which are considered the main obstacles of animal production improvement in the Sudan (Latif & Shawgi, 1982; Imam, 1995). An accurate map of distribution of these ticks countrywide is still lacking. Hoogstraal (1956) identified ticks of the Sudan but did not draw a distribution map with the exception of Equatoria Province. Current knowledge on tick distribution in the Sudan is based only on fragmentary pieces of work carried out to date. Nevertheless, several factors determine the dynamic changes of tick distribution in the Sudan. These are animal movement either for trade, nomadism, or migration due to civil unrest etc., habitat modification such as deforestation, large-scale mechanized cultivation and urbanization, drought and desertification, and global climate change.

The accelerated change in tick distribution results in outbreaks of several tick-borne diseases. Examples of these are East Coast fever, tropical theileriosis, malignant ovine theileriosis, heartwater and babesiosis by *Babesia bovis*. Emergence of these diseases in districts believed to be free is alarming and has adverse effects in the process of animal resources development. This paper discusses distribution patterns of the important livestock ticks in the Sudan and identifies new zones where ticks have established and the possible factors determining such distribution.

Possible factors influencing tick distribution in the Sudan

Animal movement

Nomadism: Animal movement from an ecological zone to another is widely considered as means of introduction of ticks into new ecosystems (Cumming, 1999). In the Sudan, about 80% of livestock are owned by the traditional sector, mostly nomads. Cattle routes (Baggara type) in South Darfur are north-south direction. The tribes that follow these routes are Ta'aisha, Fellata, Habbaniya, Benihalpa, and Rizeiqat (Abdel Rahman, 2002). They reach beyond latitude 8°N in the south and 14°N in the north. Ticks that are expected to have changed their distribution or emerged in new zones are *A. variegatum, A. lepidum, R. (B) annulatus* and *R. pretextatus* (Karrar *et al.,* 1963, Osman, 1978, Osman *et al.,* 1982, FAO, 1983, Latif & Hassan, 1997, Walker *et al.*, 2003, El Imam, 2003, Salih *et al.,* 2004, Abdalla & Hassan, 2010). In the neighbouring province of Kordofan, the tribes such as Misairiya, Hawazma and Awlad Humaid also follow certain north-south migration routes. Cattle of the latter tribe are expected to mix with cattle along the White Nile. This is significant for spread of *H. anatolicum* and *A. lepidum* to the western parts of the country. In the central Sudan, between the White Nile and Blue Nile, cattle routes of Rufa'a tribe, north-south direction, are also important in the advance of *H. anatolicum* to the south direction.

Migration: In the Republic of southern Sudan, migration of cattle of Dinka and Neur is expected to disseminate the newly introduced tick i.e. *R. appendiculatus* that is believed to be confined in Eastern Equatoria (Jongejan *et al.,* 1987). However, Zessin & Baumann (1982) detected antibodies against *Theileria parva* among cattle in Bahr el Ghazal Province.

Habitat modification

Change in vegetation cover such as deforestation, establishment of large scale agriculture schemes, drought and desertification and global climate change affects macro and microclimates, habitats of ticks and hence their existence or nonexistence.

Deforestation: Approximately 25 million acres of tropical rain forests are lost each year. The destruction of this biomass accounts for 20% of the anthropogenic CO_2 emitted into the atmosphere every year (Helikson & Jones, 2002). Sudan forests have drastically decreased during the last decades. About 1.1 million acres were deforested annually during 1980 – 1990. FAO (1997) reported that forest cover in the Sudan is estimated to be 12% of the total area of the country while it was 18% during 1980's and 36% in 1950's. Land utilization in Sudan as at 1997 is shown in Table 1. Mohamed (2000) reported that steady deforestation that has occurred over the previous twenty years under the combined effects of agricultural encroachment, fuel wood cutting and overgrazing, has reduced forest area by 20%. Deforestation in the Sudan ranges between 210,000 and 420,000 hectares within an annual average of 365,000 hectares (Mohamed, 2000).

Large-scale mechanized cultivation: Mechanized farming schemes have taken up to 4 million hectares of forest lands, some of which after 3 to 4 years of continuous sorghum cropping have been abandoned and left lying idle. Distribution of economically important ticks is expected to have been affected by manipulation of the vegetation cover. This change remains to be elucidated.

Drought and desertification: Drought and desertification have a direct and indirect effect on tick survival in the affected regions. Unfed ticks have the ability to survive for several months but succumb to high temperature and low humidities. In the Sudan, El Ghali and Hassan (2010) released ticks under direct sunlight in bare land and found that they survived for only one week while in the shade they survived for several months. Similar results had

Table 1: Land utilization in the Sudan in 1997.

Land utilization	Area*
Forest and wood-land	134.67 (22.6%)
Productive forest	52.18 (8.78%)
Shrub and desert Shrub	103.14 (17.34%)
Gazetted forests	18.41 (3.11%)
Wildlife reserves	42.24 (7.12%)
Swamps and water surfaces	3.44 (0.59%)
Arable cropped land	40.26 (6.77%)
Desert and urban	200.81(33.5%)

***** Area in million acres**.**

Source: Mohamed (2000).

been obtained by Mohamed *et al.* (2005). A prolonged drought occurred almost all over the Sudan for a succession of years (1981–1985). Karrar (1987) reported that some parts of East and West of the country had already been in the grip of moderate to severe desertification for more than two decades. The author added that due to drought and desertification, crop cultivation failed, grazing lands became barren and water wells dried up. The worst scenes were in Northern Kordofan and Red Sea Provinces. During the onset of drought prolonged overgrazing, overcultivation and deforestation aggravated the problem. Total area affected by drought and desertification was estimated at 1.5 million km^2 in the east and west of the country while millions of livestock perished. Surveys in western Sudan in 1975 revealed that desert had advanced 90 to 100 km in a 17-year period (Bayoumi, 1984). He, also, reported that the forest area decreased from 584,362 km^2 in 1968 to 559,015 km^2 in a 13-year period. These factors have tremendous impact on redistribution of the ticks. Ticks which are expected to have been affected by desertification in Kordofan and Darfur include *Hyalomma detritum*, *H. anatolicum*, *A. lepidum* and *A*. *variegatum* as discussed below.

Wildlife species are considered as alternative feeding hosts of ticks as they act as important means of dispersion of ticks. A variety of wildlife species occupy different vegetation zones that range from desert and arid lands at extreme north of the Sudan to relics of tropical rain forests in the South. These species are slowly vanishing due to desertification and relevant habitat deterioration (Bayoumi, 1984). National Parks in the country are Dinder National Park (6,400 km^2), Southern National Park (16,850 km^2), Nimuli National Park (260 km^2) and Radom National Park (12,500 km^2). Wildlife reserves are expected to be 42.24 million acres (Table 1). In the last three decades, several factors assisted in the sharp decrease of wildlife in the Sudan. These include drought, desertification, human activities such as drastic increase in mechanized agriculture at the expenses of natural range land, unauthorized hunting of wildlife and urbanization activities (Nimir, 2001). Several species of wildlife, for instance, have disappeared in Eastern Sudan, Northern Kordofan and Darfur. In Dindir National Park, only 3% of animals used to inhabit in the seventies are currently remaining (Abdel Hamid, 1999). In Radom National Park, several species of wildlife have suddenly decreased particularly elephant, giraffe, buffalo, eland, lion, tiger, ostrich (Nimir, 2001). Ticks, which particularly feed on wildlife have either changed their geographic distribution or disappeared from these parks. Examples of these ticks include *Amblyomma cohaerens, Amblyomma rhinocerotis, Dermacentor circumguttatus* and *Hyalomma bouyi*.

Global climate change: The concern over global climatic change has arisen due to the fact that the atmospheric quantities of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) are rapidly increasing. CFCs have heat holding capacities 15,000 times greater than CO_2. An increased quantity of greenhouse gases in the troposphere decreases the chances of heat energy escaping the troposphere. The following changes are likely to occur; an average warming of the Earth by 3 – 8 degrees F, outbreaks of floods or drought, proliferation of agricultural pests and an increased rate of species extinction (Helikson & Jones, 2002). The impact of global warming on distribution of ticks and emergence of tick-borne diseases in the Sudan remains to be investigated.

Ambient temperatures and relative humidities are critical factors determining longevity of ticks decreasing with high temperatures and low humidities. In Australia, 10% of ticks released in pasture during summer survived for 4 weeks while the comparative value for winter was 11 weeks (Utech *et al*., 1983). Hassan (1997) found that survival of ticks under direct sunlight was significantly shorter compared to those in the shade. Long and thick vegetation cover provides shade and optimum humidity in microhabitats of ticks thereby enhancing their survival. *Ixodes* spp. die quickly of desiccation when exposed to humidity below their critical equilibrium humidity (Stafford III, 1994). A relative humidity range of 60 – 70% was critical for *Rhipicephalus appendiculatus* below which survival of eggs and larvae was limited (Punyua, 1985). Hassan (1997) found that survival of *Amblyomma variegatum* and *R. appendiculatus* during the rainy season was significantly higher compared with dry season.

Change in tick distribution patterns in the Sudan

Amblyomma lepidum: It is classified as a dry region tick species prevalent in central and east African countries. In the Sudan, it is abundant in eastern parts of the country (Walker and Olwage, 1987; Karrar *et al.*, 1963). A significant change has occurred to this tick species due to factors such as development of large agricultural schemes, deforestation and movement of animals for search of pasture (Fig. 1). In eastern Sudan, El Amin *et al.* (1986) observed that there was a shift to the south in areas where this tick had not been reported. This was confirmed by Mohamed *et al.* (2005) who found that *A. lepidum* has become abundant in Edamazin Town (12^oN, 34^o 25' E). This species has made another shift on the west direction being abundant along the White Nile in Kosti (13^oN, $32^o35'E$), (El Imam, 2003). He found that this species outnumbered other ticks, a fact that confirms that this species is moving to the west direction (Fig. 1). It is not clear whether *A. lepidum* is replacing *A. variegatum* or not a fact which leaves the field open for further studies.

Karrar *et al.* (1963) argued that until early 1960's it was believed that *A. lepidum* did not exist to the west of the Nile in Kordofan and Darfur. Osman (1978) in his collections from many localities in Darfur found only males of *A. lepidum* from three localities. However, later, Osman *et al*. (1982) reported that *A. lepidum* which had not been common in west of the Nile according to Hoogstraal (1956) became extensively distributed in the semi arid and savannah of Kordofan and Darfur. Sowar (2002) reported that *A*. *lepidum* was the most dominant tick species in Southern Kordofan. These reports indicate that *A. lepidum* is extending its distribution to the western parts of the country. Recently, Abdalla & Hassan (2010) found this tick species abundant all over South Darfour. It is alarming that *A. lepidum* which used to be confined in eastern parts of the African continent (Walker & Olwage, 1987) may reach West African countries in the near future. This would aggravate and complicate the situation of heartwater and dermatophilosis in West African countries.

Amblyomma variegatum: This tick is also spreading to new ecosystems (Fig. 1). Hoogstraal (1956) indicated that the northern limit of *A*. *variegatum* was 12^oN. He found this tick species from Edamazien Town (12^oN, 34^o 25' E). Later, Jongejan *et al*. (1987) and Mohamed *et al*. (2005) did not encounter this tick species in Edamazien. Disappearance of *A. variegatum* could be attributed to the fact that this part of the country is where large scale mechanized agriculture schemes are established. It is, also, an area where deforestation is intensively practiced. These two important factors must have changed macro and microclimatic habitats of this tick species. In Kosti Town (13^oN, $32^o35'E$), *A. variegatum* has crossed the northern limit defined by Hoogstraal (1956) as reported for the first time by El Imam (2003). It was also reported from El Obied Town (13^oN, 30^oE) (Salih *et al.,* 2004). Sowar (2002) observed in Dilling Town (12^oN, $28^o75'$) that *A*. *variegatum* disappears from animals during the dry season from December to April while *A. lepidum* is prevalent throughout the year. Animal movement is responsible for *A*. *variegatum* to cross the northern limit set by Hoogstraal (1956), especially in Darfur where it has established in Nyala area (Abdalla & Hassan, 2010). However, capability of *A*. *variegatum* to establish and survive in dry hot area of Elobied and Nyala remains to be investigated.

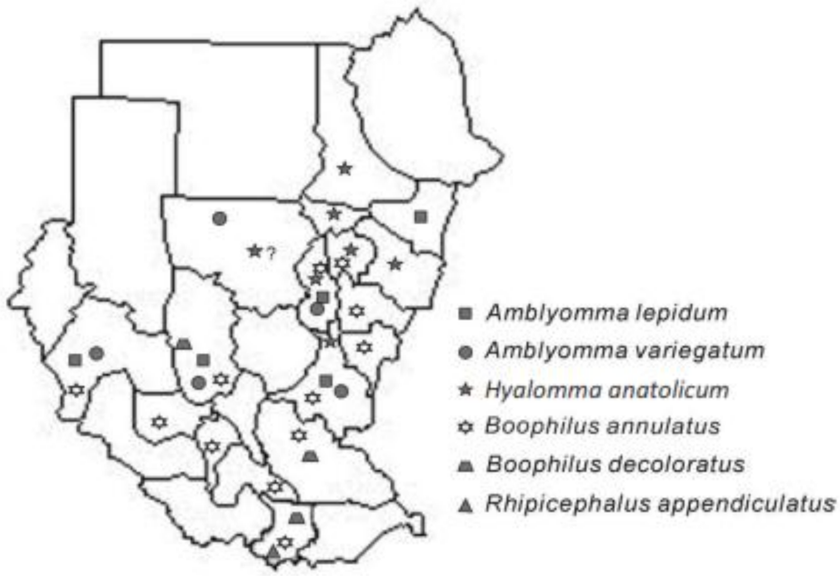

Figure 1: Geographical distribution of important ixodid ticks in Sudan

Hyalomma anatolicum : It is a xerophilic species thriving in semi-desert conditions in Northern Sudan (Fig.1). Jongejan *et al.* (1987) considered latitude 14^{o}N to be its southern limit. It is spreading southwards in the Central Sudan. In the early 1980s, this tick species was not reported at Um Benain (13^{o}N, 34^{o}E) (FAO, 1983) along the White Nile. Twenty years later, this species established in this locality (Salih *et al*., 2004). It has also extended its distribution along the White Nile to Kosti (13^{o}N, 32^{o}35'E) according to El Imam (2003) who found this species and *H. excavatum* for the first time in this ecosystem. However, he did not find these two tick species only 60 km and beyond to west of the Nile (Fig. 1). He attributed this absence to the husbandry regime where these tick species are only able to propagate inside cattle pens and do not infest cattle kept under outgrazing or nomadic systems. Animal movement and macroclimate change due deforestation and large-scale mechanized agriculture schemes could be responsible for movement of *H. anatolicum* on the south direction although it does not inhabit high humid zones. This tick species has not been recorded in western parts of the country. In Nuba Mountains, western Sudan, Osman *et al.,* (1982) among several *Hyalomma* species did not encounter *H. anatolicum*. Similarly, Sowar (2002) did not find this species in Dilling (12^{o}N, 28^{o}75', about 100 Km south of El Obied). In an ad hoc tick collection (Salih *et al.*, 2004) did not encounter this species in El Obied (13^{o}N, 30^{o}E), Nyala (12^{o}N, 24^{o} 50'E), El Ginaina (13^{o}50'N, 22^{o}30'E), nor El Fashir (13^{o} 70'N, 24^{o}45^{o}E). However, unconfirmed reports indicate that this species has established in El Obied. This is substantiated by outbreaks of clinical theileriosis among exotic cattle and by high seroprevalence of *T. annulata* antibodies by ELISA conducted by Salih (2003). Animal movement along the White Nile could be responsible for *H. anatolicum* invading El Obied. In a recent tick collection from Northern Kordofan (Mohammed-Ahmed, 2011) *H. anatolicum* was not recorded. Recently, Abdalla & Hassan (2010) identified a considerable number of *H. anatolicum* in Nyala (Fig. 1). Earlier Osman (1978) had collected only one male of *H. anatolicum* in Darfur from a donkey on a single occasion. This confirms that this tick species has established in Nyala, but has not yet spread to other localities of Darfour. Introduction of this species into Darfur was due to the recent introduction of Friesian cattle and their crosses from *H. anatolicum* infested area such as Khartoum and Central Sudan into South Darfur region. Introduction of *H. anatolicum* that could be infected with *Theileria annulata* into a non-tropical theileriosis endamic area such as South Darfur is alarming. Likewise, *A. lepidum, H. anatolicum* is steadily spreading from its ever known distribution zone of Eastern and Central Sudan (Jongejan *et al*., 1987) to western parts of the country. It will not be surprising for this economically important tick species to reach in the near future to the far West African countries carried by animals that cross the international borders to Chad, Niger and Nigeria.

Rhipicephalus (Boophilus) annulatus: It is considered a tick of humid area, was recorded in southern Sudan by Hoogstraal (1956) who pointed out that *R. (B) annulatus* had been reported from West Africa, Central Africa and certain parts of southern Sudan. It is now spreading to the northwards to much drier zones (Fig. 1). This is most likely due to continuous animal movement. FAO (1983) recorded this tick species as far north as Wad Madani (14°.25' N, 32° 75'E) being abundant along the Blue Nile from Sennar (13°50'N, 32° 75'E) to Edamazin. It is difficult to explain why this tick of high humidity is able to survive in the drier ecological zones of Central Sudan. Along the White Nile, El Imam (2003) encountered this species in Kosti. Osman (1978) reported *R. (B) annulatus* in Southern Darfur for the first time. Later, Osman *et al*. (1982) found this species in several locations in Southern Kordofan being prevalent throughout the year. Sowar (2002) observed in Kordofan that *R. (B) annulatus* has reached a stage where it is able to outnumber *R. (B) decoloratus.* Abdalla & Hassan (2010) confirmed that *R. (B) annulatus* has established in all localities of South Darfur (Fig. 1). Since during the dry season (November to April) cattle from Darfur region enter Bahr El Ghazal Province where this tick species is abundant (Zessin & Baumann, 1982) they must be the source of introduction of this species into Darfur during the wet season (May to October). The possibility that *R. (B) annulatus* is replacing the coexisting *R. (B) decoloratus* is open for future studies.

It is noteworthy that the west African tick *Rhipicephalus (Boophilus) geigyi* has been collected from Southern Sudan, near Bor Town (6 °10'N, 30° 75') (Jongejan *et al*., 1987). This may not be surprising because this tick species had been reported from two districts in Uganda near the borders with the Sudan (Matthysse & Colbo, 1987). However, Jongejan *et al*. (1987) argued that there have been various intrusions of West African tick fauna into the Sudan and re-examination of *Rhipicephalus (Boophilus)* collections may reveal more *R. (B) geigyi*. Nevertheless, the consequences of introduction of this new tick species in relation to tick-borne diseases have to be seriously considered. On the other hand, although *R. (B) geigyi* was reported in Central Republic of Africa (Walker *et al.,* 2003), but it was not found in the survey conducted by Abdalla & Hassan (2010). It is difficult to explain its absence in this region despite the fact that animals cross the borders to and from Chad in search of water and pasture. Similarly, these authors did not find *Hyalomma detritum* although Hoogstraal (1956) reported this species from Darfur area. Osman (1978), also, had not found this tick species in the same area. Probably, it has disappeared due to some climatic changes. On the other hand, prevalence of the West African tick species *R. muhsamae* in relatively large numbers in collection of Abdalla & Hassan (2010) from Darfur is an indication that it is spreading in the eastern direction most probably through animal movement.

Rhipicephalus appendiculatus: In the neighbouring country, Republic of South Sudan, *Rhipicephalus appendiculatus* was first reported in Kajo Kaji near Ugandan borders (Hoogstraal, 1956). In late 1970s with the influx of Ugandan refugees owned cattle, this tick species was introduced into the Sudan and established in eastern Equatoia (Morzaria *et al*., 1981). In 1986, the Mundari herdsmen were forced to move their cattle from Terekaka (60 Km north of Juba) to Juba Town due to insecurity caused by the civil war (Fig. 1). On their return, ECF and *R. appendiculatus* were introduced in Terekaka (Julla, 2003). There is fear of spread of this species to extend its advance further north to Bor and the swampy area of Jongelei or to intrude Bahr El Ghazal Province which is free from *R. appendiculatus* (Zessin and Baumann, 1982). This tick species has not been identified among ticks collected from cattle in Makakal ecosystem in a cross sectional survey (Elfagiri & Hassan, 2010, unpublished data). It is to be investigated whether *R. appendiculatus* is found in southern Sudan in foci and will be spontaneously eliminated and has permanently established and has spreading in all directions. The complications arise from the fact that CLIMAX shows that southern Sudan is not a suitable ecosystem for survival of *R. appendiculatus* (Latif & Hassan, 1997). On the other hand, the impact of the civil war and insecurity must have forced herdsmen to change their traditional routes, grazing areas, time of grazing, or to keep their animals in new localities where they have never been before. The impact of such change in husbandry on distribution of ticks and emergence of tick-borne diseases should be determined.

In conclusion the accelerated change in tick distribution results in outbreaks of tick-borne diseases in non-endemic areas. Examples of these are East Coast fever in Southern Sudan (Salih *et al.,* 2007), tropical theileriosis in Western Sudan (Abdalla

& Hassan, 2010), malignant ovine theileriosis in Khartoum State (Tageldin *et al.*, 1992), heartwater in Eastern Sudan (Abdel Rahman *et al.,* 2003) and babesiosis in White Nile State (Abdel Rahman, 2013). Emergence of these diseases in districts believed to be free is alarming and has adverse effects on the process of animal resources development. The areas at risk of East Coast fever in Southern Sudan are Unity State, Lakes State and Bahr elghazal region whereas most of the southern parts of Central Sudan are at risk of tropical theileriosis and malignant ovine theileriosis. There is an urgent need to embark upon drawing a map of geographic distribution of ticks countrywide and to lay a long-term plan for a regular periodic monitoring and updating information. These studies should include prevalence and abundance of ticks, seasonal population dynamics, emergence of tick-borne diseases in non-endemic areas, replacement of a tick species to another coexisting one. Such project requires an interdisciplinary cooperation among tick ecologists and taxonomists, agriculturists, social scientists, and climatologists.

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