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Review

Current Limitations in the Control and Spread of Ticks that Affect Livestock: A Review

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Abstract: Ticks are well-known parasites that affect livestock productivity. This paper reviews the current knowledge regarding the spread of ticks with their impact in animal health and the limitations to achieve effective control measures. The forecasted trends in climate play an obvious role in promoting the spread of ticks in several regions. It appears that climate warming is pivotal in the spread and colonization of new territories by *Rhipicephalus microplus* in several regions of Africa. The reported increase in altitude of this tick species in the mountainous regions of Central and South America appears to be driven by such general trends in climate change. This factor, however, is not the only single contributor to the spread of ticks. The poor management of farms, uncontrolled movements of domestic animals, abundance of wild animals, and absence of an adequate framework to capture the ecological plasticity of certain ticks may explain the complexity of the control measures. In this paper, we review several details regarding the relationships of ticks with the environment, wild fauna and competition with other species of ticks. Our intention is to highlight these relationships with the aim to produce a coherent framework to explore tick ecology and its relationship with animal production systems.

Keywords: ticks; domestic animals; climate; spread; control strategies

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1. Introduction

Tick-borne pathogens affect 80% of the world's cattle population and are widely distributed throughout the world, particularly in the tropics and subtropics [1]. Ticks are responsible for a variety of losses that are caused by the direct effect of attachment ("tick-worry"), injection of toxins, or through the morbidity and mortality associated with the pathogens that they transmit, together with secondary problems as the enhancement of transmission of Dermatophilosis, myiasis or udder damage by *Amblyomma* spp. [1]. The estimated annual global costs associated with ticks and tick-transmitted pathogens in cattle amounted to between US$ 13.9 billion and US$ 18.7 billion [1]. In Africa, tick-borne diseases are considered the most important animal disease problem [2]. In Australia, it has been estimated that the losses due to cattle ticks, except for the wounding and rendering of animals susceptible to myiasis, are 65% related to anorexia and 35% related to blood loss [3]. Cattle ticks of the genus *Rhipicephalus*, formerly part of the genus *Boophilus*, in Australia are responsible for between a 0.6 g [4] and 0.9 g [5] reduction in the gain of live weight of cattle for each tick that matures to a detached engorged female. Thus, there is a reduction of approximately 600–900 g per animal during the three weeks comprising the feeding period of the tick under conditions of low infestation. These numbers could increase to greater than 2 kg during the same time period under conditions of medium to high infestation by these ticks. The equivalent information for *R. appendiculatus* in Africa is 4 g per tick [6] and 46–61 g per tick for *Amblyomma variegatum* [7]. Infestations by the latter species are not as high under field conditions, but in any case, the total reduction in the gain of live weight could be as much as 6 kg per month in addition to the spread of selected pathogens. Information regarding the reduction in the yield of milk has been technically difficult to obtain and no good estimates are available worldwide. Thus, the economic burden of the diseases transmitted through ticks is a serious limiting factor for the economic development of developing countries and a concern in areas where these diseases have been previously eradicated [8]. It has been concluded [9] that there is no single, ideal solution for the control of ticks because tick control is only one component of farm management.

Recent studies have addressed the possible causes and trends related to the introduction and spread of foreign species of ticks into a territory [10–13]. The causes of tick introduction and spread include the uncontrolled movements of domestic or wild animals, small but sustained climate trends, and changes in the use of land resources that allow for the increased abundance of tick hosts. After ticks are introduced to a region, they may persist only if the climate is compatible with the requirements of the ticks and if sufficient hosts are available. Upon the introduction of ticks into territories where no competition with other species of ticks exist, they will most likely colonize the complete range of abiotic conditions that is compatible with their physiological plasticity, similar to that which occurred in Australia with *R. australis* or western Africa with *R. microplus* [13]. Detailed surveys of ticks introduced into foreign territories exist only in the United States [14–16]. Whereas there are no empirical records regarding the persistence of introduced tick populations in the US, these reports should be a caution regarding uncontrolled importation practices and the risk of introducing foreign tick-transmitted pathogens.

Despite widely recorded evidence that climatic patterns, including temperature and rainfall patterns, have direct effects on the survival rates of ticks, there are reservations about the

potential for predicting future effects of global climate change on the prevalence of vector-borne pathogens [17–29]. These studies examined alternatives to climate-driven hypotheses for the epidemiology of vector-borne pathogens and generally identified the need for a greater understanding of the ecology of these pathogens to better understand and predict the effects of future changes in the environment on these vector-borne pathogens. The survival, establishment, and spread of a tick population depend on climate, geographic factors, and host species and distribution.

This review focuses on our understanding of the processes behind the spread of several tick species that affect animal health, with attention to the main variables that affect their biology and colonization patterns. We will not focus on the logistics of treatments or the need to further advance our knowledge towards the integrated control of ticks because adequate reviews already exist [9,30,31]. Furthermore, a recent review has addressed the biological contributors for the control of ticks [32]. Even with several uncertainties associated with tick-climate-landscape systems, knowledge is gained related to the direct effects of climate and its general regulatory effects on tick populations, which are linked to many factors that are derived from the biotic (hosts) component of the system. Our aim in this review is to produce a foundation for discussion of the different and variable factors that affect the spread of ticks, which in some cases, seems to be wrongly evaluated because of misconceptions regarding tick biology.

2. Background: Ticks, Climate, Landscape and Human Forces

The lack of empirical estimates of the prevalence and incidence of tick-transmitted pathogens makes it difficult to determine their impact, particularly on a countrywide scale. There are, however, some general estimates of the economic effects of tick parasitism [5,8,33–36] based on some of the pathogens they transmit [37,38]. Some tick-transmitted pathogens each have a particular tick species vector, so the potential distribution of each pathogen may be estimated from the distribution of its vectors. Other pathogens may be transmitted by several tick vectors, but its potential distribution can be assessed by mapping of the respective vectors. The potential distribution of the vector, however, is not always an accurate reflection of the presence of the disease. For example, in some cases, the vector may be present but the pathogen has either not been reported or has been eradicated. When a tick spreads into a new territory, it may carry pathogens. By contrast, a pathogen may be transmitted by ticks and other vectors, such as *Anaplasma marginale*, which is mechanically transmitted through fly bites or blood-contaminated fomites [39]. For *A. marginale*, the absence of the tick does not necessarily indicate the absence of some strains of the pathogen. This situation is illustrated by *Theileria parva*, the causative agent of classical East Coast fever, which was eradicated from the Republic of South Africa approximately 40 years ago, although its tick vector, *Rhipicephalus appendiculatus*, remains abundant.

Nevertheless, the general distribution of ticks is the principal indicator used to estimate the distribution of tick-transmitted pathogens. Therefore, the interest behind tick survey is not only faunistic because accurate tracking of the distribution of a tick may provide additional information regarding the ecological conditions, such as the climate and vegetation, to which they are exposed. Most ticks spend long periods of their total life cycle in the field, exception being the long parasitic phase observed in one-host ticks. During this time, they search for a host or moult from one instar to the next. Temperature is the only regulator of the moults of ticks [30], and each tick species can

develop adequately at optimal rates only under a set of thermal conditions. Similarly, a water saturation deficit in the air, rather than rainfall or relative humidity, is correlated with the survival and activity rates of ticks. Both temperature and water content regulate the persistence of permanent populations of ticks in the field, provided that hosts are available at adequate densities. Therefore, we can infer the abiotic factors regulating tick distribution by correlating the climate and vegetation constraints with the pattern of known records of ticks. This also allows for the detection of environmental variables that have effects on the observed pattern of distribution using a correlative model. However,, basic knowledge of the distribution constraints gained by such an effort may be obscured by wrong species determinations in the original reports that are not adequately addressed in the compilation. Further studies have been performed for the Palearctic [40] or the Afrotropical [41] regions, which were based on a large set of records that was adequately curated by specialists in the taxonomy of ticks. These studies outlined the main abiotic constraints determined from the reported distribution of ticks.

Predicting the impact of climate change on the epidemiology of tick-transmitted pathogens, however, is neither a trivial nor straightforward exercise. This has been highlighted [42] mentioning that "predicting and mitigating the effects of future changes in the environment like climate change on the complex arthropod–pathogen–host epidemiological cycle requires understanding of a variety of complex mechanisms from the molecular to the population level". Please refer to the original article [42] for a full discussion of the impact of climate change on vector-transmitted pathogens. Species of ticks with a large distribution area are able to survive in a large range of climate traits whether they should be considered generalists, which are loosely adapted to the prevailing climate conditions or because of the perception of "regional" well-adapted to the local prevailing conditions. In the first case, ticks could easily adjust to a given set of abiotic conditions. In the second case, the spread of ticks from one site to another should be problematic because of the lack of genotypes that match the abiotic conditions at the invasion point. This variability in adaptation to a variable range of climate conditions is called ecological or phenotypical plasticity, and has been investigated in other insects [43] but not yet in ticks. The lack of knowledge regarding the ecological plasticity of ticks affects our ability to predict the areas of potential invasion, which are defined also by the geographical barriers to dispersion and the host range available for ticks. This lack of knowledge affects any further forecast of the spread of ticks. The potential invaded range can only be estimated based the complete potential of the invasive population. However, even with complete knowledge of the origin of the invading strain, its physiological limits or how it would adapt in the absence of competing traits that are found in its native range are ignored. Therefore, as shown in the examples below, climate is not always the only factor to consider when investigating the potential drivers of the spread of ticks and the associated lack of control of a tick population.

Tick control involves the control of tick-transmitted pathogens through a reduction in the number of ticks infesting the host. Serological evidence suggests that former practices regarding the need to maintain a minimum number of ticks on animals to ensure endemic stability to cattle babesiosis were most likely wrong [9,44,45]. Additional academic research may identify novel targets for acaricide action, but without commercial commitment, this research is unlikely to impact tick control. Furthermore, diagnostic tests of ixodicide resistance in the field rather than laboratory remain non-trivial. According to [9] even more demanding than the diagnostic tests is the need to translate a

diagnosis of acaricide resistance into a management recommendation that a producer will implement. Currently, there are no guidelines to produce a recommendation to the farmer after resistance is detected. The effects of anti-tick vaccines or tick resistant host genotypes may be more complex because of the possibility that these control methods may also affect pathogen transmission [9,30]. Tick vaccines have been developed that induce immunological protection of vertebrate hosts against tick infestations. The feasibility of controlling tick infestations through the immunization of hosts with selected tick antigens was demonstrated by the development of vaccines based on the recombinant Bm86 protein that is derived from the gut of *Rhipicephalus (B.)* spp. and is used to induce a protective immune response that reduces cattle infestations [9,30,46]. However, as mentioned [9] tick control based on vaccine has not yet reach its optimum performance because logistic constraints and a lack of understanding by farmers and animal managers of its mechanism of action. The potential for vaccines and acaricides to act in a synergistic manner is scientifically interesting [1] but has not been fully explored.

3. Current Status of the Most Prominent Ticks Affecting Animal Health

3.1. Eradication of the Cattle Ticks Rhipicephalus (Boophilus) *spp. in United States*

The almost total success in the eradication of cattle fever ticks (former *Boophilus* spp.) in the southern U.S. is a classic example of a coordinated action to eliminate a threat through chemical treatment and restriction of the movements of infested animals. The cattle fever ticks, *R. annulatus* and *R. microplus*, are serious threats to animal health and production economics in many countries of Central and South America. These tick species are also recognized as an emerging threat to the animal economy of the United States [47] because of the potential for re-introduction and spread to large areas of the US, from Texas to Florida. *R. microplus* originated in Asia before it was transported and spread to much of Central and South America as well as the southern United States. *R. annulatus* is native to the Mediterranean basin and Near and Middle East. By the latter part of the 19th century, bovine babesiosis was the major deterrent to the development of a strong cattle industry in the southern United States. When the national tick eradication campaign began in the United States in 1906, the tick-infested area included all or parts of 14 southern states and a portion of southern California, an area of 1,813,000 km^2. By 1943, the national eradication campaign was declared complete even though these ticks remained in Texas along the Rio Grande River, and the last pocket of *R. microplus* in Florida was not eliminated until 1960 [48]. An extensive background on the efforts for eradication of these ticks in the territory of the U.S. has been published [31] that must to be accounted for a complete understanding of the historical situation of these ticks in the region.

The long-term effects of climate on the life cycle of *R. microplus* have been addressed [49] studying a large area covering the complete range of the tick in the New World. It was recognized that the cyclical components of the main regulatory factors of the climate in the region could produce periodic waves of more suitable habitat in the region that could improve the abilities of the tick to survive in territories that were formerly considered too cold for colonization. Therefore, climate has been recognized as one of the constraints to any *R. microplus* eradication effort. Because *R. microplus* is a one-host tick, the occurrence of large populations is limited only by an adequate range of temperatures and available water, provided that bovine hosts are abundant [49,50]. Robust simulations have

provided adequate data to understand the dynamics of the tick in pastures and how management strategies may affect such phenology [51,52]. However, problems in insuring that the U.S. cattle industry remains protected against fever ticks and babesiosis also include the presence of acaricide-resistant *R. microplus* in Mexico, changes in plant communities that improve tick habitat, and an abundance of alternative hosts [53,54]. Information regarding the historical problems of wildlife in the US tick eradication program has been thoroughly reviewed [55]. After the creation of the Livestock Sanitary Board for the eradication of the cattle tick in the U.S., it was soon recognized that cattle living near game preserves did not respond to the usual two-week dipping scheme for tick control. The white-tailed deer (WTD, *Odocoileus virginianus*) was hypothesized to sustain and spread large populations of ticks, and it is assumed that a series of outbreaks of *R. microplus* in the southeastern US were produced by WTD, although no tick-infested deer were observed during any of the tick recurrences in Florida between 1945 and 1960. Similar problems related to WTD were observed in the tick eradication campaign in Puerto Rico, and it was demonstrated that *R. microplus* could exist in a natural environment with WTD as the sole host. However, when tick-infested deer and cattle share the same range, the ticks can be eradicated by dipping the cattle regularly [56]. It was concluded that WTD are physiologically suitable hosts and that they could disseminate the tick [57]. For *R. annulatus*, a study of deer from a large area in Texas demonstrated that WTD can be infested by these ticks and that the deer are capable of transporting the ticks to uninfested pastures [58]. Outbreaks of both *R. microplus* and *R. annulatus* occur periodically in the southern counties of Texas where the U.S. is separated from Mexico by the Rio Grande River. At times, the limited flow of water in the river makes it easy for tick-infested domestic animals to be brought across the river from Mexico [55]. It is believed that large populations of infested wildlife may concentrate near the river and transport ticks across the river, far from the buffer zone that was designed to restrict movements of infested animals in the area [47].

In the U.S., the spread of these ticks is a multifactorial problem. A study has demonstrated the total number, location and probable reasons for the cattle tick outbreaks recorded in Texas over a period of 25 years [47]. In addition to the development of resistant ticks in Mexico, the situation is further complicated by the existence of former lands that were allocated to cattle pasturing, which have since been converted into areas of deer farming for hunting purposes. Therefore, whereas cattle are systematically controlled to avoid the spread of ticks between the Mexico-U.S. border, deer can freely roam across both sides of the border. This situation leads to probable breaks of the quarantine barrier at sites where wild fauna are concentrated [10]. Increasing numbers of failures of the pasture vacation approach to tick eradication from the 1970's to the present are known to be related to the abundance of WTD and perhaps other wild ungulate species [59]. Evidence confirms previous reports on the importance of white-tailed deer in supporting the dispersal and maintenance of both *R. microplus* and *R. annulatus* within the permanent quarantine or buffer zone in south Texas along the Rio Grande, as well as in the so-called free ("cattle fever tick-free") area north and east of the buffer zone and extending to the east coast of the United States. It must to be understood that white-tailed deer not only provide ticks with a way to escape the systematic application of acaricides, but they also provide an abundant source of blood, which allows the ticks to experience large increases in population [59]. These factors are clearly aggravated by the expected higher survival rate of ticks because of the continuous climate trend in this region.

3.2. Rhipicephalus microplus *and Other Regions of the World*

Rhipicephalus microplus is a serious pest of domestic cattle in many parts of the world. We remain ignorant as to the native range of *R. microplus*, although it is most likely on the Asian continent. However, *R. microplus* has been reported as invading large areas of eastern Africa, South Africa, and recently, parts of the Ivory Coast and Benin [12]. The ticks in the former genus *Boophilus* (now considered to be a part of *Rhipicephalus*) are commonly named boofilids; this common name is used in this paper in order to avoid continuous reference to the complete generic plus subgeneric names. Formerly believed to be the same species in Australia, it is now believed that the only boofilid tick present in Australia is a close species, *R. australis*, which has been largely confused with *R. microplus* for over 100 years [60]. Several *R. microplus* hot spots exist in Africa, and the factors involved in regulating of the spread of ticks at each location appear to be the same. The tick spreads, displacing local species of boofilids, until it reaches some gradient of temperature and water availability. The situation in Tanzania [61] and South Africa [62] has been examined the events in Tanzania. *R. decoloratus* is indigenous and widespread in the African continent, whereas *R. microplus* was introduced to South Africa by cattle that were imported from Madagascar after the rinderpest epidemic in 1896 [62]. During the early 1900's, reports suggested that *R. microplus* was displacing *R. decoloratus* in the Cape Province of South Africa [62] and later reports from South Africa confirmed this displacement [61]. It appears that the spread of *R. microplus* is advancing more quickly than during the previous 100 years. It would appear that a viable *R. decoloratus/R. microplus* hybrid that is similar to the sterile hybrids described between *R. microplus* and *R. annulatus* is unlikely [63,64]. One might speculate that the shorter life cycle of *R. microplus* and the tendency towards assortative mating and successful feeding may provide *R. microplus* an advantage over *R. decoloratus*. Assortative mating is a nonrandom mating pattern where individuals with similar genotypes and/or phenotypes mate with one another more frequently than what would be expected under a random mating pattern [65]. There thus appears to be a zone of reproductive interference where *R. decoloratus* and *R. microplus* overlap in South Africa, but experimental evidence regarding this zone is much too scant to draw any firm conclusions as to the extent to which this zone may either contain or prevent the spread of *R. microplus*. It has been suggested [66] that reproductive interference is ineffective in preventing *R. microplus* from spreading when climatic conditions are favourable, cattle have no acquired resistance to *R. microplus* and cattle movements are common. The displacement of *R. decoloratus* in these areas appears to be rapid and complete and may be related to rapid adaptations to climate conditions by *R. microplus*, in which the ticks suddenly readjust to what were previously restrictive conditions at the border of their environmental niche. Analysis of the data from Tanzania demonstrates that the critical factor for the advance of *R. microplus* and the retreat of *R. decoloratus* is associated with the 58 mm isohyet and the 22–23 °C isotherm. This indicates a well-developed higher temperature tolerance for *R. microplus*. The distribution pattern of the boofilids in Tanzania that was recorded in this study could not be satisfactorily explained by the mere displacement of one species by the other. Rather, this distribution pattern resembled a parapatric coexistence of two competing species that meet equilibrium on a climatic gradient, whereas dispersal maintains an overlap zone where the species continue to interact [61].

Early in 2007, during a small-scale survey of the ticks infesting cattle in the Ivory Coast, *R. microplus* was recorded for the first time in West Africa [67]. No *R. annulatus* or *R. geigyi* were recovered, although they had previously been recorded in this region. The presence of *R. microplus* was further confirmed by extensive surveys in Benin [12,13]. The importation of Girolando cattle from Brazil to the Ivory Coast and Benin most likely caused the introduction of *R. microplus* to these countries [13]. Initially, it was hypothesized that the spread of *R. microplus* would be limited and localized to the areas near the farms where the Girolando cattle were first introduced, which would allow for tick eradication. The speed with which the replacement of *R. annulatus* and *R. geigyi* by *R. microplus* occurred in West Africa is alarming. *R. microplus* has colonized half of Benin in less than a decade and has displaced indigenous ticks of the same genus in many sampled locations [12] even at sites where the climate is drier. It is quite possible that this tick has not yet reached its full climatic range and it may spread further north into more arid regions during the following years. This finding suggests that we are far from a complete understanding of the sudden adaptation of *R. microplus* to regional climate conditions and that such knowledge cannot be gained from the analysis of surveys from different parts of the world because local processes that have not yet been identified may be involved in these regional adaptations.

The spread of *R. microplus* to several parts of Africa is a limited representation of our knowledge regarding tick biology. It is obvious that the spread of ticks is a consequence of the uncontrolled movement of domestic animals into a tick naive territory; however, the reasons behind the rapid adaptation to prevailing regional climate conditions are not well understood. Studies [61,66] shed light on the basic processes of competition between tick species. However, drivers of the rapid adaptation of *R. microplus* to new environments that are within its physiological limits are unknown. Additional research on the physiology of these ticks under changing environmental conditions will undoubtedly produce a significant body of knowledge.

A different situation could appear in many parts of the Neotropics if climate trends are sustained. *R. microplus* is the only boofilid on the continent, and there is no direct competition with other tick species, similar to the situation reported in Africa. Therefore, the distribution of *R. microplus* is expected to track its climate niche, which has been studied from previously reported records [50]. No sudden changes in the distribution of *R. microplus* as a consequence of adaptation to new conditions have been reported (Guglielmone, pers. comm). The current warming trend in the Neotropics only contributes to enlarging the area of climatic suitability. Under adequate conditions of host presence, which are necessary to support the population of ticks, this risk of expansion may extend south into latitudes 33–34°S [49,50]. This is similar to the situation currently recognized in Colombia (Benavides, pers. com.), where permanent populations of *R. microplus* have been observed at high altitudes in an area called the "High-altitude Tropics" where cattle grazing is maintained at roughly 3,000 meters above sea level. Additionally, this area was traditionally free of *R. microplus* because of the limiting effects of temperature. It has been observed that the tick is present on grazing animals at altitudes that are higher than where the tick was present in the recent past. Although the relaxing of control measures by chemical pressure seems to be involved in the spread of *R. microplus*, the situation has not been entirely addressed, but warmer temperatures appear to be behind this switch in altitude.

3.3. Amblyomma variegatum *in the Caribbean*

The tropical bont tick arrived on cattle from Senegal in 1830 [66], and it is considered a severe potential threat to the cattle industry of the Americas because it is a vector of *Ehrlichia ruminantium* [67,68]. This tick has been considered a serious danger for the US cattle industry because it could spread from the Caribbean to the coasts of Florida. The invasive behavior of *A. variegatum* is not related to climate, but it is related to the translocation of the ticks to sites where a minimum chance of development and survival exists. Other than cattle, the tick can persist in feral donkeys and stray, small ruminants. The uncontrolled movements of domestic animals between the islands are further complicated by the existence of a large population of cattle egrets on which immature ticks easily feed [69]. These egrets disperse to nearby islands and invalidate classic campaigns of control that are focused on domestic animals.

Amblyomma variegatum was eradicated from four islands of the Caribbean during the early years of the 21st century by a campaign run by the Food and Agriculture Organization in association with the US Department of Agriculture and other agencies [70]. The original objective of the campaign was to eradicate this tick from the entire region, and the implementation phase lasted 12 years. This campaign included 18 nation states or islands and was funded and directed from afar by five main international development agencies, but without clear managerial lines of authority. This led to severe operational problems that often confounded the stoical efforts of the small group of scientific and administrative staff based in the Caribbean [70]. Termination of the coordinated efforts before the eradication was complete led to a situation in which, after large investments, the tick persists in several islands of the zone, and without adequate control pressure, it will most likely spread to nearby islands that have not yet been invaded. Additionally, the tick may reach continental South America or the US coast [69].

Concerns regarding the further spread of ticks to the continents have arisen from the modeling of the preferred climate niche of the tick [71]. However, it must be noted that the physiological limits of an invading organism depend upon its plasticity and the phenotype of the spreading "seeds". *Amblyomma variegatum* is adapted to a wide range of climate conditions in its natural distribution range [72] and it is risky to speculate about the physiological limits that the invading population can endure and how it will respond to the new climate conditions. It appears that the climate conditions of the nearby continents do not closely match the conditions that are preferred by the tick, as was previously believed. However, it is difficult to reliably support this hypothesis because of the uncertainties regarding the basic premises of the adaptability of the tick to regional climate conditions. There is no data regarding the consequences of a massive translocation of the tick to the nearby continents. Therefore, efforts geared towards the total eradication of the tick in the Caribbean should be completed with an appropriate combination of enforcement and proper management. The risk derived from both the uncontrolled movements of stray animals on the island and from the unpredictable movements of cattle egrets is a major reason to achieve complete eradication, which is not driven by mechanisms of either acaricide resistance or climate trends.

4. Conclusions

Livestock contribute to natural, financial, human, physical and social capital in different ways and to different degrees within smallholder dairy, crop–livestock and livestock-dependent systems. All of

these production systems are at risk from ticks and tick-transmitted pathogens. Ticks are responsible for losses caused by their attachment to animal hides, by the injection of toxins, and/or by the transmission of pathogens that reduce production or cause mortality. The lack of available estimates of the prevalence and incidence of each tick-borne disease makes it difficult to determine their impact. Designing an economical, integrated tick control strategy for a particular production system in a specific area is one of the more difficult challenges facing farmers in developing countries. Appropriate extension activities must provide farmers with the information necessary to enable them to design and evaluate sustainable strategies that are suitable for the control of ticks under their particular conditions. Whereas climate is most likely the major driving force in the processes behind the regulation of the life cycle of ticks, it is not the only such factor. The ecological plasticity of the tick seems to be highly variable, both between and within taxa, in particular regarding the absence of competition with other species. The general mechanisms regulating this adaptive behavior are unknown. This is one of several factors that we need to understand and manage before attempting tick control campaigns. By contrast, ticks introduced to sites where they were previously absent may present a different behavior regarding the use of hosts compared to their native areas. These questions must be urgently addressed to further improve animal health. Ignoring alternative hosts may introduce potential problems when a control campaign against ticks is outlined, even at a regional scale, because hosts not targeted with the application of acaricides may support large, hidden tick populations. Finally, the uncontrolled movements of domestic animals remain the primary reason behind the large numbers of ticks that are introduced from their native territories into far regions. Examples are the increased populations of white -tailed deer in the U.S. and *R. microplus/R. annulatus*, the uncontrolled importation of domestic cattle to Africa, which introduced *R. microplus*, or the spread of *R. australis* into New Caledonia from Australia during the Second World War. A thorough knowledge of tick biology, including the results of new experiments performed in the laboratory to determine how ticks react to changing environments, is required to gain the necessary information to address these challenges.

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