

The current status and predicted climate-driven range expansion of *Rhipicephalus microplus* in northern Vietnam

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ABSTRACT

Rhipicephalus microplus is a major ectoparasite of cattle, significantly impacting animal health and livestock productivity in tropical and subtropical regions. This study investigated the current status and predicted the future distribution of *R. microplus* in northern Vietnam under climate change scenarios. Field surveys were conducted across 25 provinces from 2022 to 2024, collecting data on tick infestation by province, season and host species. Statistical analyses were performed by multivariable logistic regression. To forecast future distribution, the MaxEnt model was employed under RCP-4.5 and RCP-8.5 climate scenarios for the years 2050 and 2070.

The presence of *R. microplus* was confirmed in 80.6 % of survey sites, with a higher prevalence observed during the summer and autumn seasons. Statistical analysis revealed that season and host species were significant predictors of tick presence. The MaxEnt model projected an expansion of suitable habitats for *R. microplus* toward higher latitudes and altitudes, especially under the high-emission scenario (RCP-8.5).

This is the first study to combine field-based prevalence data with climate-driven MaxEnt modeling for *R. microplus* in Vietnam. The findings highlight the potential impact of climate change on tick ecology and underscore the need for adaptive control strategies to mitigate the spread of tick-borne diseases in northern Vietnam.

1. Introduction

Rhipicephalus (Boophilus) microplus, known as the Asian blue tick, is the most significant tick species affecting livestock worldwide, owing to tick-borne pathogens it may transmit (Estrada-Peña et al., 2006; Jongejan and Uilenberg, 2004). The prevalence of *R. microplus* is strongly associated with economic losses, particularly in cattle farming (Grisi et al., 2014). However, it has also been observed infesting other domestic and game animals, including buffaloes, horses, dogs, sheep, and goats (da Silva et al., 2018; Pound et al., 2010).

Rhipicephalus microplus is a one-host tick species, meaning that the larvae quest for a host, and after attachment and blood-sucking they molt to the nymph, and then (following another blood meal) to the adult

stage on the same host individual (Oyen and Poh, 2025). This usually takes three weeks to complete. In tropical regions, *R. microplus* can be active year-round, producing up to six generations per year (Oyen and Poh, 2025). This tick species is the primary vector of protozoan and bacterial pathogens such as *Theileria equi*, *Babesia bovis*, *Babesia bigemina*, and *Anaplasma marginale*, which cause equine theileriosis, bovine babesiosis and anaplasmosis, respectively (Futse et al., 2003; Jongejan and Uilenberg, 2004). Economic losses attributed to these pathogens are estimated to range between US\$14–19 billion annually (de Castro, 1997). The year-round activity and current epidemiological significance of *R. microplus* in the cattle industry of Vietnam has recently been reconfirmed (Hornok et al., 2024).

The distribution and population dynamics of *R. microplus* are

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strongly influenced by environmental factors, particularly temperature, humidity and host availability (Estrada-Peña et al., 2012). Climate change is anticipated to significantly alter the ecological niches of many vector species, including ticks, by modifying habitat suitability and expanding their geographical ranges into previously non-endemic areas (Gilbert, 2021; Ogden and Lindsay, 2016). In Southeast Asia, including Vietnam, the effects of climate change are becoming increasingly evident, with rising temperatures and changing precipitation patterns potentially reshaping the epidemiology of vector-borne diseases (Linh Tran et al., 2023). Given the dependence of *R. microplus* on climatic conditions for development, survival, and reproduction, understanding its current distribution and modeling its potential future spread under climate change scenarios is essential for effective surveillance and control strategies.

Recently it was established with molecular barcoding and phylogenetic methods that it is *R. microplus* and not *Rhipicephalus australis* that occurs in Southeast Asia (Prasetyo et al., 2025). Nevertheless, despite its importance and reports on its genetic diversity or carrier status in the context of tick-borne pathogens in Indochina (Tantrawatpan et al., 2022; Thinnabut et al., 2024), comprehensive data on the seasonality, host-associations and ecological determinants of *R. microplus* in Vietnam and its region remain limited (Yean et al., 2025). Furthermore, predictive modeling approaches that assess the future distribution of this species under climate change scenarios are still underreported in Southeast Asia. Species distribution modeling (SDM), particularly using algorithms such as MaxEnt (Maximum Entropy), are widely used in predicting the potential distribution of vector species by integrating occurrence data with climatic and environmental variables (Peterson et al., 2011; Phillips et al., 2006). By applying such models, it is possible to forecast future tick habitats and to prioritize high-risk areas for intervention.

In Vietnam, research on ticks and tick-borne pathogens has become intensified. Recently, the number of ixodid tick species known to occur in Vietnam increased from 62 to 66 (Hornok et al., 2024; Huynh et al., 2021). However, previous studies have primarily focused on identifying ticks on various hosts. There have been no large-scale investigations into the epidemiological distribution of *R. microplus* across different regions, nor in the seasonal variations of its distribution in northern Vietnam. Moreover, no studies have predicted the future distribution of *R. microplus* under climate change scenarios using the MaxEnt model. This study aims to investigate the geographic, seasonal, host-related and predicted distribution of *R. microplus* under climate change scenarios in northern Vietnam.

2. Methods

2.1. Study area and environmental data

In northern Vietnam, the weather varies according to four seasons. These are defined as follows: spring lasts from March to May, summer from June to August, autumn from September to November, and winter from December to February of the following year. There are three geographical subregions including the Red River Delta, mountainous northeast, and mountainous northwest. Three provinces of Ha Noi, Thai Nguyen and Son La were selected to represent each subregion, respectively. Ha Noi belongs to the Red River Delta region with plain and midland, average temperature of the year is about 23.6 °C, rain 1800 mm per year, and moisture is about 79 %. Thai Nguyen represents mountainous regions in the northeast with low and medium mountainous terrain, average temperature of the year is 21.5–23 °C, rain 2200–2500 mm per year, moisture in the range of 70–90 %. Son La is another mountainous region in the northwest of Vietnam with high mountainous terrain, average temperature of the year is about 21–22.5 °C, rain 1400–1700 mm per year, moisture is about 81 %.

For seasonal sampling, two communes were selected randomly from each province to represent various pastured species of animals

(buffaloes, cattle, horses, and goats). In total, 25 communes of 9 districts in three provinces (Ha Noi, Thai Nguyen and Son La) of northern Vietnam (Table 1) were included in the study. The coordinates of communes were downloaded from GeoHack (<https://geohack.toolforge.org/>) and the administrative boundaries of the provinces were obtained using polygon shapefiles from the DIVA-GIS (<http://www.diva-gis.org/gdata>).

2.2. Tick collection and identification

Rhipicephalus microplus was collected from cattle, buffaloes, goats and horses kept on pastures in spring, summer, autumn and winter seasons, from June 2022 to June 2023. The whole body surface of each animal was inspected carefully for the presence of ticks which were removed using forceps and placed in separate labeled tubes containing 96 % ethanol. The tubes were then transported to the National Institute of Veterinary Research, Hanoi. The collected ticks were identified at the species level through a stereo zoom microscope Nikon SMZ745 C LEDS (Japan), using standard morphological identification keys and illustrations (Kanduma et al., 2020; Kazim et al., 2022; Šlapeta et al., 2022; Trapido and Hoogstraal, 1964; Walker A.R., 2003). For identification of on-host *R. microplus* larvae and to distinguish these from larvae of other *Rhipicephalus* species, molecularly identified *R. microplus* larvae collected from the vegetation in Cuc Phuong National Park on March 28, 2024 were used as voucher specimens (Supplementary Figure 1).

One specimen of *R. microplus* was randomly selected from each province for molecular analysis. Ticks were washed in physiological saline solution (0.9 %) and distilled water, then were cut and digested with lysis buffer and proteinase K at 56 °C overnight. DNA was extracted with the QIAamp DNA Mini Kit (QIAGEN, Hilden, Germany). Conventional PCR was used randomly to confirm tick species with the primers LCO1490 (forward: 5'-GGT CAA ATC ATA AAG ATA TTG G-3') and HCO2198 (reverse: 5'-TAA ACT TCA GGG TGA CCA AAA AAT CA-3') (Folmer et al., 1994; Lv et al., 2014). The reaction mixture, in a volume of 25 µL, contained 10 µL Master Mix, 0.5 µL (1 µM final concentration) of each primer, 9 µL ddH₂O and 5 µL template DNA. The PCR was applied under the following conditions: an initial denaturation at 95 °C for 5 min, followed by 40 cycles of denaturation at 94 °C for 40 s, annealing at 48 °C for 1 min, and extension at 72 °C for 1 min, with a final extension at 72 °C for 10 min. The PCR products were then sequenced and analyzed to confirm species identity. The newly obtained sequences of the cytochrome *c* oxidase subunit I (*cox1*) gene were submitted to GenBank with the following accession numbers: Hanoi – PQ856124 (760 bp), Thai Nguyen – PQ856325 (757 bp), and Son La – PQ856129 (770 bp).

2.3. Predicted distribution under climate change

Current and future (2050 and 2070) bioclimatic data were obtained from WorldClim (<http://www.worldclim.org/bioclim>) at a spatial resolution of 30 arc-seconds (~1 km²). Using ArcGIS 10.8 and MaxEnt 3.4.4, the distribution of *R. microplus* was modeled based on 19 bioclimatic variables clipped to northern Vietnam. Future climate scenarios (A2a) were derived from the HadGEM2-ES model under the IPCC AR5 framework and downscaled using current climate baselines (Hijmans et al., 2005). MaxEnt was used to evaluate variable contributions through percentage contribution, jackknife analysis, and AUC from 500 model replicates (Mischler et al., 2012). A total of 10,024 background and 25 presence points were used, with regularization multipliers set for feature types: linear, quadratic, product (0.346), categorical (0.250), threshold (1.750), and hinge (0.500). Model performance was assessed by AUC values, where higher scores indicated better predictive accuracy (Mischler et al., 2012; Phillips et al., 2006). Non-contributory variables (BIO5, 10, 13, 17, and 18) were excluded and the model was recalibrated. Future distributions for 2050 and 2070 were projected under RCP 4.5 and RCP 8.5 scenarios. The details of bioclimatic variables and

Table 1

The distribution and regression analysis of relationship between *R. microplus* and province, season, and host.

Characteristics	Mean	SD	Univariable		Multivariable	
			IRR (95 %CI)	P	aIRR (95 %CI)	P
Province						
Ha Noi	1.38	3.84	1.32 (0.98–1.78)	> 0.05	1.26 (1.04–1.54)	< 0.05
Thai Nguyen	1.27	2.90	1.22 (0.90–1.64)	> 0.05	1.29 (1.07–1.55)	< 0.05
Son La	1.04	2.64	Reference		Reference	
Season						
Spring	0.96	2.76	1.47 (1.04–2.07)	< 0.05	1.32 (1.02–1.70)	< 0.05
Summer	1.28	3.01	1.96 (1.40–2.75)	< 0.001	1.35 (1.06–1.73)	< 0.05
Autumn	2.02	4.36	3.10 (2.22–4.35)	< 0.001	2.0 (1.57–2.51)	< 0.001
Winter	0.65	1.85	Reference		Reference	
Host						
Buffalo	0.72	1.86	3.91 (2.74–5.57)	< 0.001	3.81 (2.50–5.80)	< 0.001
Cattle	2.95	5.14	15.88 (11.31–22.32)	< 0.001	11.64 (8.04–16.85)	< 0.001
Goat	0.83	1.74	4.49 (3.15–6.39)	< 0.001	3.70 (2.60–5.27)	< 0.001
Horse	0.19	0.72	Reference		Reference	

Note: aIRR- adjusted incidence rate ratio, CI-confidence interval.

percent contributions are shown in Supplementary Table 1.

2.4. Statistical analysis

The distribution data of *R. microplus* were calculated as mean, standard deviation (SD) by province, season and host. The mean prevalence values of *R. microplus* were determined by dividing the total number of ticks collected by province, season and host by the number of hosts or sampling locations according to province and season. The Zero-inflated Negative Binomial Regression analysis was used to assess risk factors including province, season and host. Exact confidence intervals (CI) for the incidence rate ratio (IRR) were calculated at the 95 % level. The predicted number of *R. microplus* was calculated after adjustment with geography, host and seasons throughout the year. Variables with $P < 0.10$ in univariable screening were adjusted for multivariable models. All data were analyzed using statistical packages in STATA version 18.0 (Stata, College Station, Texas, USA).

3. Results

3.1. Current geographical distribution of *R. microplus* in northern Vietnam

A total of 2952 *R. microplus* were collected from 593 out of 2400 examined domestic animals in three provinces in northern Vietnam. The number of ticks according to developmental stages was 57 larvae, 592 nymphs, 1881 females and 422 males. The data revealed significant variability in *R. microplus* prevalence and infestation levels across different provinces. For instance, Van Hoa and Tan Linh (Ha Noi) exhibited a particularly high mean prevalence of *R. microplus* (5.92 and 3.10, respectively). In contrast, Kim Lan (Ha Noi) and Trang Xa (Thai Nguyen) were recorded with low prevalence of *R. microplus* (0.03 and 0.3, respectively) (Fig. 1).

The highest mean prevalence of *R. microplus* was recorded in Ha Noi, i.e., 1.38 (SD = 3.84). Thai Nguyen had a slightly lower total mean tick prevalence of 1.27 (SD = 2.90), whereas Son La presented the lowest infestation rate among the provinces, with a total mean of 1.04 (SD = 2.64) (Table 1).

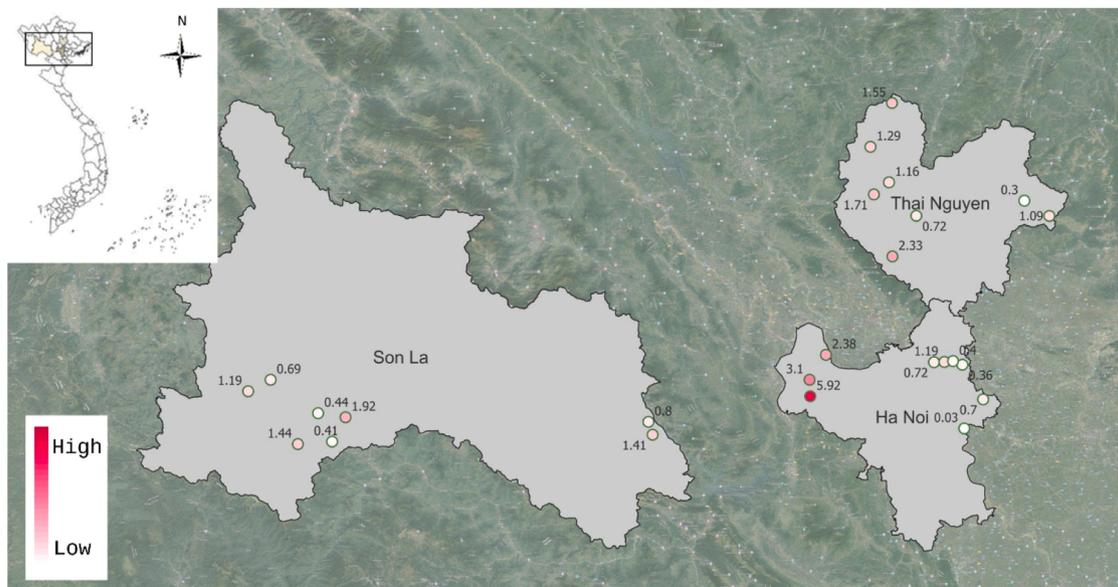


Fig. 1. The mean prevalence of *R. microplus* in northern Vietnam.

3.2. Seasonal distribution of *R. microplis*

Seasonal distribution analysis indicated that *R. microplis* was most prevalent in the autumn with mean of 2.02 (SD =4.36). Summer followed with a total mean of 1.28 (SD = 3.01). Spring and winter periods showed lower densities, with total means of 0.96 (SD = 2.76) and 0.65 (SD = 1.85), respectively (Table 1).

Results of the univariable model regression analysis indicated a substantial increase in *R. microplis* during the summer and autumn seasons compared to the reference season (winter). Specifically, the IRR for autumn was 3.10 (95 % CI: 2.22–4.35, $p < 0.001$), and it was 1.96 (95 % CI: 1.40–2.75, $p < 0.001$) for summer. The spring season also showed a statistically significant difference from the reference category,

with an IRR of 1.47 (95 % CI: 1.04–2.07, $p < 0.05$). These findings highlight the pronounced seasonal effects, with peak activity of *R. microplis* in the autumn and summer, as also confirmed by multi-variable analyses and adjusted incidence-rate ratios (aIRR) (Table 1).

3.3. Host-associated distribution and density of *R. microplis*

Host specificity analysis revealed that cattle were the most commonly infested host for *R. microplis* with mean of 2.95 (SD = 5.14). Goats, buffaloes and horses had significantly lower *R. microplis* densities, with total means of 0.83 (SD = 1.74), 0.72 (SD = 1.86), and 0.19 (SD = 0.72), respectively (Table 1).

Based on the results of regression analysis, cattle had the highest

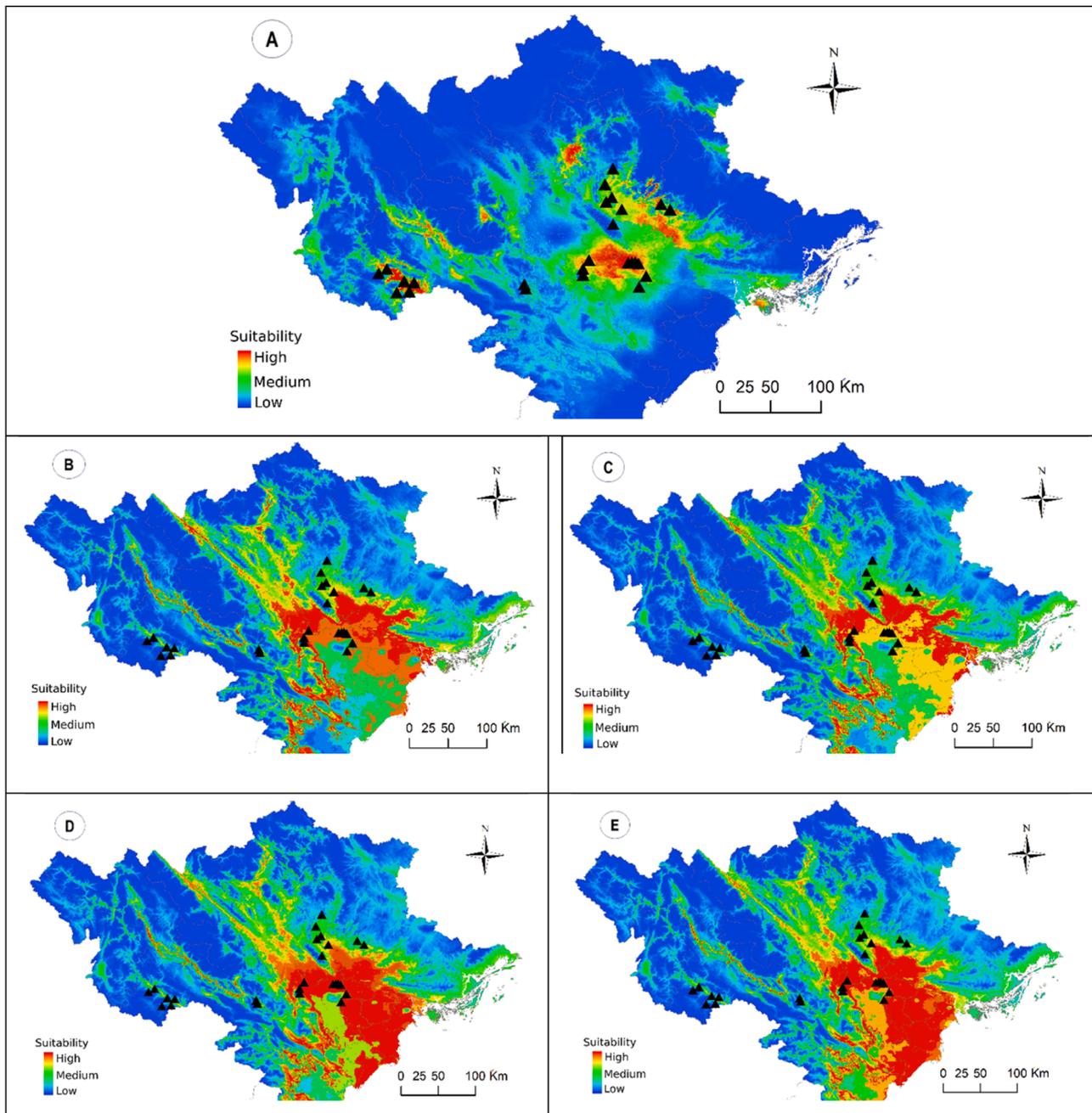


Fig. 2. Current and predicted distribution of *R. microplis* under climate change. (A) Current distribution of *R. microplis* in northern Vietnam; (B&C) Predicted distribution of *R. microplis* under climate change in 2050 with RCP - 4.5 and 8.5; (D&E) Predicted distribution of *R. microplis* under climate change in 2070 with RCP - 4.5 and 8.5. The color gradient represents habitat suitability, with blue, green to yellow and orange to red as low, moderate and high suitability areas, respectively. The black triangles indicate confirmed presence records of *R. microplis* from field surveys.

level of *R. microplus* infestation, with an IRR of 15.88 (95 % CI: 11.31–22.32, $p < 0.001$), indicating that cattle were significantly more likely to host *R. microplus* compared to the reference host (horses). Goats and buffaloes also showed significantly higher prevalence of *R. microplus*, with IRRs of 4.49 (95 % CI: 3.15–6.39, $p < 0.001$) and 3.91 (95 % CI: 2.74–5.57, $p < 0.001$), respectively. Based on these data, cattle are the primary host for *R. microplus*, followed by goats and buffaloes. These results were confirmed by multivariable analyses and aIRR values (Table 1).

3.4. Predicted geographical distribution of *R. microplus* in northern Vietnam

The current distribution model indicates that *R. microplus* is predominantly found in lowland and mid-altitude regions of northern Vietnam, characterized by warm temperatures and high humidity. The most influential bioclimatic variables affecting *R. microplus* distribution include temperature factors such as Annual Mean Temperature (BIO1), Temperature Seasonality (BIO4), and Minimum Temperature of Coldest Month (BIO6), which determine tick survival and reproduction rates. Additionally, precipitation-related factors such as Annual Precipitation (BIO12), Precipitation of Wettest Quarter (BIO16), and Precipitation of Coldest Quarter (BIO19) influence tick development and host availability. Areas with moderate and stable climatic conditions support the highest tick densities, while extreme temperatures or excessive rainfall may limit their presence Fig. 2.

Under RCP - 4.5 for 2050, the model predicts an expansion of *R. microplus* into higher altitude regions as warming temperatures create new suitable habitats. However, some lowland areas may experience reduced suitability due to excessive heat. Under RCP - 8.5, a significant northward shift is projected, with *R. microplus* colonizing regions previously unsuitable due to colder temperatures. Extreme heat in some areas may reduce tick populations, leading to localized contractions. By 2070, under RCP - 4.5, the distribution remains stable but continues expanding into northern highlands, where rising temperatures make conditions more favorable. Under RCP - 8.5, the model suggests widespread distribution, but climate extremes may create unsuitable conditions in certain regions, particularly in areas experiencing prolonged drought or excessive heat stress.

4. Discussion

This study investigated the host-associations, seasonality, current and predicted geographical distribution of *R. microplus* due to climate change in northern Vietnam. A total of 2952 *R. microplus* were collected from 593 out of 2400 examined domestic animals, revealing significant variability in tick prevalence and infestation levels across the studied provinces. Climate change is considered a global problem, affecting the geographical distribution of *R. microplus* in Latin America, Africa and particularly in the Indo-Malayan region (Marques et al., 2020). The present findings confirm this scenario for the first time in Vietnam. Both northern provinces had significantly higher infestation rates compared to Son La, likely due to variations in climatic conditions, host availability and farming patterns (Estrada-Peña et al., 2017). The higher prevalence in Ha Noi may be due to the high number and density of livestock, which are ideal conditions for tick survival and reproduction. These results draw attention to differences between countries of Southeast Asia, because the distribution of *R. microplus* has recently been reported to be similar between different sampling sites in Cambodia neighboring Vietnam (Yean et al., 2025).

Seasonal variations also play a critical role in tick infestation dynamics. The highest mean tick infestation in this study in northern Vietnam was recorded during autumn (September to November), with a significantly higher ratio compared to winter. This is again different from what has been observed in Cambodia, with peak activity of *R. microplus* in May–July (Yean et al., 2025). These differences are most

likely climate-related, because northern Vietnam experiences four seasons (under subtropical climate), while in Cambodia dry and rainy seasons alternate under tropical climate.

The difference in *R. microplus* density clearly shows that weather factors, including temperature and humidity, are the main factors affecting the growth and development of tick populations. This pattern aligns with previous studies indicating that warm and humid conditions favor the survival and reproduction of *R. microplus* (Ali et al., 2019; de la Fuente et al., 2008). However, summer is the season with the highest average temperature and humidity in northern Vietnam. Accordingly, summer should be the season with the highest number of ticks. This can be explained by the fact that in summer, farmers often use tick control measures, so the number of ticks decreases in summer, as also reported in Africa (Dzemo et al., 2024). Meanwhile, farmers do not use acaricides in the fall, so the number of ticks increases rapidly. These results show that it is necessary to increase the time of using acaricides in both summer and autumn, suggested for the whole region of Southeastern Asia (Yean et al., 2025).

Host specificity analysis revealed that cattle exhibited the highest mean tick burden and the greatest adjusted incidence rate ratio compared to other domestic animals. This finding is consistent with existing literature that identifies cattle as the primary host of *R. microplus*, attributable to factors such as larger body size, increased exposure to pasture environments, and thinner skin, which facilitate tick attachment and feeding (Jonsson and Hope, 2007; Labruna et al., 2009). While goats and buffaloes also showed significantly higher infestation levels than horses, the magnitude of infestation remained substantially lower than that observed in cattle. Horses, by contrast, had the lowest infestation rates, suggesting reduced suitability or preference by *R. microplus*, potentially due to host-specific behaviors or physiological factors (Walker et al., 2003). These results confirm the host preference of *R. microplus*, highlighting cattle as the dominant host, which has direct implications for disease transmission, given the tick's role as a vector of bovine pathogens such as *B. bovis*, *B. bigemina*, and *A. marginale* (Jonsson and Hope, 2007). From a practical standpoint, these findings underscore the importance of prioritizing cattle in targeted tick control and surveillance strategies to mitigate the risk of vector-borne diseases. Furthermore, the variation in infestation among hosts supports the need for the implementation of species-specific integrated tick management approaches that consider host susceptibility and ecological interactions (Abbas et al., 2014; George et al., 2004).

The current distribution of *R. microplus* suggests that this ectoparasite thrives in regions with suitable climatic conditions, particularly warm and humid environments, which facilitate its survival and reproduction. Therefore, these regions will be likely affected by animal health implications, such as increased risk of pathogen transmission. However, projected climate changes under different Representative Concentration Pathway (RCP) scenarios suggest notable shifts in its potential range, which may have significant consequences for livestock health and disease transmission. Under the RCP 4.5 and RCP 8.5 scenarios for 2050 and 2070, the predictive models indicate an expansion of *R. microplus* into previously less favorable regions. These projections align with existing literature data indicating that climate change is likely to enhance the survival and establishment of *R. microplus* in new geographical areas due to shifts in temperature and humidity (Estrada-Peña and Salman, 2013; Ogden and Lindsay, 2016), as already witnessed in Asia (Bhangale and Narladkar, 2023) and Africa (Nyangiwe et al., 2017). The increase in suitable habitats may imply that the tick's reproductive cycle may be enhanced by rising temperatures, leading to higher population densities and prolonged activity periods.

Conversely, some regions may experience reduced suitability due to extreme climatic conditions, such as prolonged droughts or excessively high temperatures, which can negatively affect tick survival (Kamani et al., 2017). This suggests that while certain areas will become more conducive to the occurrence of *R. microplus*, others may become less hospitable, leading to a redistribution rather than a universal expansion.

The implications of these shifts are profound for livestock management and disease control, because economic losses may change in a different way depending on geographical region, necessitating sophisticated coordination of control measures.

While the results of this pilot study are important for designing and installing effective control measures against *R. microplus* in Southeast Asia, there were some limitations which should be improved in future, larger scale investigations of the topic. For instance, the spatial scale was restricted to three provinces in northern Vietnam, the temperature could not be continuously monitored. In addition, using absence data as background in MaxEnt implies that unanimous application of presence-background method will be inevitable to improve occurrence probability.

5. Conclusions

This study highlights the significant impact of climate change on the distribution of *R. microplus*, with potential expansion into new regions and contraction in others. These shifts increase the risk of tick-borne diseases, emphasizing the need for proactive surveillance and control strategies. Integrating climate projections into vector management will be crucial for mitigating economic and public health risks. Future research should refine predictive models by considering additional ecological factors. Addressing these challenges requires a multidisciplinary approach to ensure sustainable tick control and disease prevention.

Ethical statement

Ticks were collected from the body of animals during regular veterinary care, therefore no ethical permission was needed.

CRediT authorship contribution statement

Duan Pham Ngoc: Writing – original draft, Investigation, Data curation, Conceptualization. **Thanh Dao Thi Ha:** Writing – review & editing, Project administration, Conceptualization. **San Nguyen Ngoc:** Supervision, Conceptualization. **Minh Pham Ngoc:** Supervision, Conceptualization. **Ngoc Duong Nhu:** Methodology, Investigation, Data curation. **Róbert Farkas:** Methodology, Conceptualization. **Sirinya Teeraananchai:** Data curation. **Sándor Hornok:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no competing interests

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.actatropica.2025.107732.

Data availability

Data will be made available on request.

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