

Climate Change and Its Potential Effects on Tick Life Cycle, Distribution, and Tick-Borne Parasite Transmission in Aljabel Alghrbi, Libya

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ABSTRACT

Climate change can modify the environmental conditions that regulate tick survival, development, seasonal activity, geographic distribution, and interactions with vertebrate hosts. Ticks are particularly relevant to public and veterinary health because they transmit a wide range of pathogens, and their ecology is strongly influenced by temperature, humidity, vegetation, host availability, and seasonal conditions. This examines the potential relationship between climate change and tick ecology, with particular attention to the Aljabel Alghrbi region of Libya. the together with on climate-sensitive tick biology, tick distribution in Libya and North Africa, and tick-borne infections. Evidence indicates that warming may accelerate development and extend periods of activity in some tick species, whereas excessive heat, drought, and low humidity can reduce survival. Climate change may therefore alter tick distribution and seasonal dynamics rather than producing a uniform increase in abundance. Recent studies from Libya demonstrate substantial diversity of hard ticks on livestock and clear seasonal differences in abundance, supporting the need for local ecological surveillance. The available evidence does not support attributing changes in tick-borne disease risk to temperature alone. For Aljabel Alghrbi, there is a clear need for longitudinal field surveillance combining standardized tick sampling, species identification, climatic measurements, host and habitat assessment, molecular detection of pathogens, and spatial analysis. Such data would provide the empirical basis required to determine how climate variability is affecting local tick populations and associated health risks.

Keywords: climate change; ticks; temperature; humidity; Hyalomma; Rhipicephalus; tick-borne pathogens; Aljabel Alghrbi; Libya; vector ecology

الملخص:

يُعد تغير المناخ أحد العوامل البيئية التي يمكن أن تؤثر في بيئة القرد ودورة حياته وتوزيعه الجغرافي ونشاطه الموسمي، وذلك من خلال التغير في درجات الحرارة والرطوبة والأمطار والغطاء النباتي وتوافر العوائل، وتكتسب دراسة القرد أهمية خاصة لأن عدداً من الأنواع ينقل مسببات مرضية تؤثر في صحة الإنسان والحيوان، ومن بينها أنواع من البابيزيا والانا بلازما والريكستا وغيرها من المسببات المرتبطة بالقرد. وتهدف هذا الدراسة إلى تقييم العلاقة المحتملة بين تغير المناخ وبيئة القرد، مع التركيز على منطقة الجبل الغربي في ليبيا، ومناقشة ما هو معروف عن الأنواع المسجلة في ليبيا، والعوامل التي يمكن أن تحدد بقاء القرد ونشاطه وانتشاره، وتشير الأدلة الحديثة إلى أن ارتفاع الحرارة قد يسرع التطور ويغير التوقيت الموسمي للنشاط ضمن الحدود الفسيولوجية المناسبة، إلا أن الحرارة المرتفعة جداً والجفاف وانخفاض الرطوبة قد تؤدي في المقابل إلى زيادة الإجهاد المائي وانخفاض البقاء. لذلك لا يمكن افتراض أن ارتفاع درجة الحرارة يؤدي بصورة تلقائية إلى زيادة كثافة القرد. وتشير الدراسات الليبية الحديثة إلى وجود تنوع واضح للقرد على حيوانات المزرعة، بما في ذلك أجناس الهيالوما وغيرها، مع اختلاف في الوفرة بين العوائل والأشهر والمناطق، وسُجلت ثمانية أنواع من القرد الصلب في دراسة ميدانية حديثة، وهو ما يؤكد أهمية الدراسات المحلية. حيث لا تتوفر حتى الآن بيانات طويلة كافية تسمح بإثبات أثر تغير المناخ بصورة سببية على تجمعات القرد في الجبل الغربي، ولذلك توصي الدراسة بإنشاء برنامج رصد متعدد المواسم يجمع بين التعرف المورفولوجي والجزيئي للقرد، والقياسات المناخية الدقيقة، وتسجيل العوائل والغطاء النباتي واستخدامات الأرض، والكشف الجزيئي عن المسببات المرضية، وتحليل البيانات مكانياً وزمنياً. ومن شأن هذا النهج أن يوفر أساساً علمياً لتقييم المخاطر الصحية والبيطرية ووضع استراتيجيات مكافحة مناسبة في ليبيا.

INTRODUCTION

Climate change is altering temperature and precipitation patterns and can consequently modify ecological systems and the distribution of infectious diseases. Arthropod vectors are particularly sensitive to environmental conditions because many aspects of their development, survival, host-seeking behavior, and reproduction are temperature-dependent. Ticks are especially important in this context because they spend much of their life cycle away from the host, where microclimate conditions can determine whether eggs, larvae, nymphs, and adults survive and complete development. Climate effects on ticks are therefore expressed through a combination of temperature, relative humidity, precipitation, vegetation, soil and shelter conditions, host availability, and land use rather than through temperature in isolation (Gray et al., 2009; Ogden and Lindsay, 2016; Gilbert, 2021; Nuttall, 2022).

The epidemiological importance of these ecological changes lies in the relationship between tick abundance, host availability, pathogen persistence, and the frequency of host–vector contact. A longer period of tick activity may increase opportunities for feeding and pathogen transmission, but disease risk is not determined by temperature alone. Changes in vegetation, livestock distribution, wildlife abundance, land use, animal movement, human behavior, and pathogen prevalence can modify transmission patterns and may either amplify or counteract climate-driven effects. Recent reviews emphasize that climate and anthropogenic drivers act together and that the resulting effects can be multifaceted or even ambiguous (Lee and Chung, 2023; Mordecai et al., 2024).

North Africa and the Mediterranean basin are particularly relevant because several tick genera, including *Hyalomma* and *Rhipicephalus*, are adapted to warm or semi-arid environments. Recent evidence also demonstrates that *Hyalomma marginatum* is strongly associated with Mediterranean climatic conditions and that its dispersal can be influenced by climate, host movements, and migratory birds. These findings are important for Libya because the country contains Mediterranean, semi-arid, steppe, and desert environments that can support different tick assemblages (Estrada-Peña et al., 2007; Celina and Černý, 2025).

Libya already has a documented tick fauna associated with domestic animals. A national survey reported multiple species of *Hyalomma* and *Rhipicephalus* on livestock, while more recent studies in Tarhuna and Qarabulli have demonstrated substantial local diversity and seasonal variation. In Qarabulli, a 2024 study collected 717 ticks from 775

examined hosts and identified eight hard-tick species, including *H. excavatum*, *R. sanguineus*, *H. dromedarii*, *H. marginatum*, *H. anatolicum*, *R. annulatus*, *H. rufipes*, and *Boophilus microplus* (Shebani et al., 2024). These local observations provide a stronger basis for discussing climate sensitivity than generalized assumptions about tick expansion.

The Aljabel Alghrbi region is of interest because its ecological heterogeneity, livestock production, agricultural landscapes, and contact between domestic animals and natural habitats may create multiple microhabitats suitable for ticks. Nevertheless, the existing literature does not yet provide a sufficiently long time series to determine whether recent climatic variation has caused a measurable change in tick abundance or geographic distribution in this region. The central objective of this review is therefore to synthesize the biological mechanisms linking climate to tick ecology, summarize the evidence available from Libya and neighboring regions, and identify a practical surveillance framework for Aljabel Alghrbi.

LITERATURE REVIEW APPROACH

Recent evidence was incorporated from peer-reviewed studies published between 2022 and 2026 where relevant, including a 2024 field study from Qarabulli, a 2025 systematic review of *H. marginatum* in Europe, a 2025 systematic literature review of tick and tick-borne pathogen distributions in North and West Africa, and a recent MENA-focused review addressing climate change and One Health responses. The review does not claim to be a systematic review or meta-analysis; consequently, it does not calculate pooled effect sizes. Instead, evidence is compared qualitatively, with particular attention to the strength of inference and the distinction between established observations and hypotheses.

TICK BIOLOGY, LIFE CYCLE, AND ENVIRONMENTAL DEPENDENCE

The tick life cycle comprises egg, larval, nymphal, and adult stages. Depending on species, one-, two-, or three-host life cycles occur. Each developmental stage has specific requirements for feeding, molting, reproduction, and survival. Temperature influences developmental rates and the timing of transitions between stages, whereas humidity and microhabitat conditions are particularly important during off-host periods. Consequently, climate acts through several linked pathways rather than through temperature alone.

Temperature generally accelerates ectothermic physiological processes within an optimal range. Moderate warming can shorten development time and, in suitable environments, may permit ticks to complete developmental transitions more rapidly. However, this

relationship is not linear indefinitely. At high temperatures, water loss, metabolic stress, and mortality can increase, particularly when relative humidity is low. Thus, the same increase in air temperature can have different ecological consequences depending on the moisture conditions surrounding the tick.

Relative humidity is especially important because questing and off-host survival are constrained by desiccation. Ticks may reduce water loss by moving into shaded vegetation, soil litter, animal shelters, cracks, or other humid refugia. Consequently, measurements of regional air temperature alone can be insufficient to explain tick abundance. Fine-scale microclimatic variables may differ substantially from weather-station measurements, especially in agricultural and semi-arid landscapes.

Precipitation influences tick ecology both directly and indirectly. Rainfall can increase local humidity and vegetation growth, potentially improving survival of stages that are sensitive to desiccation. It can also alter host behavior, vegetation structure, and availability of resting sites. Conversely, prolonged drought may reduce suitable microhabitats even when mean temperature remains within a favorable physiological range. Recent climate research therefore supports the use of temperature, rainfall, humidity, vegetation, and land cover jointly rather than treating temperature as a single predictor.

Host availability is another critical component. Adult ticks often feed on large domestic or wild mammals, whereas immature stages may use smaller mammals and birds. Changes in livestock density, grazing patterns, wildlife abundance, or migratory bird movements can therefore modify tick population dynamics independently of climate. The 2025 systematic review of *H. marginatum* emphasizes that climate suitability alone does not guarantee establishment; host availability, animal movement, and ecological connectivity are also necessary (Celina and Černý, 2025).

TEMPERATURE, HUMIDITY, AND TICK ACTIVITY

The relationship between temperature and tick abundance is expected to be nonlinear. Moderate warming may reduce cold-related mortality, shorten developmental periods, and extend seasonal activity. In contrast, extreme heat, prolonged drought, and low relative humidity may increase desiccation and mortality. Ogden and Lindsay emphasized that ticks differ from many insect vectors because their environmental dependence and life-cycle structure generate complex responses to weather and climate (Ogden and Lindsay, 2016).



An important consequence is that climate warming may alter the timing of tick activity without necessarily increasing annual abundance. For example, a species may begin host-seeking earlier in spring or remain active later in autumn while experiencing reduced survival during exceptionally hot and dry periods. Such changes could modify the overlap between ticks and hosts and thereby influence the probability of pathogen transmission even when total annual tick numbers remain unchanged.

Recent research reinforces the importance of considering extreme events as well as average climate. A 2024 study showed that *Ixodes ricinus* can survive prolonged flooding and resume host-seeking after water levels recede, demonstrating that unusual weather events may not always produce straightforward reductions in tick populations. Although *I. ricinus* is not a principal species discussed for Libya, the finding illustrates why surveillance should record extreme rainfall and other unusual events rather than relying only on monthly means.

At the global scale, recent modeling using tens of thousands of occurrence records indicates that future suitability for pathogenic tick species may shift under different greenhouse-gas scenarios and that both temperature- and precipitation-related variables contribute to projected changes. Such global models are useful for hypothesis generation, but they should not be interpreted as direct evidence for local change in Aljabel Alghrbi without local occurrence and environmental data.

CLIMATE CHANGE AND TICK DISTRIBUTION

Climate can determine the geographic suitability of habitats for ticks by affecting survival, development, seasonal activity, and host–tick encounters. Evidence from Mediterranean ecosystems demonstrates that several species have distinct climate niches. Modeling of Mediterranean tick species has shown that projected warming combined with reduced rainfall can alter habitat suitability for *R. bursa*, *R. turanicus*, and *H. marginatum* (Estrada-Peña et al., 2007). This result is particularly relevant to North Africa because Mediterranean and semi-arid climatic conditions occur across large parts of Libya. *Hyalomma* species provide a useful example of the interaction between climate and dispersal. *H. marginatum* is adapted to steppe, scrubland, and Mediterranean environments characterized by hot summers and low to moderate humidity. The recent systematic review by Celina and Černý (2025) compiled evidence from 144 publications

and concluded that established populations are concentrated mainly in southern Europe and the Balkans, while sporadic records in more northern regions are often associated with animal movements or migratory birds. The review also emphasizes that establishment requires suitable climatic conditions together with appropriate hosts and ecological connectivity.

Climate-driven range change should therefore be understood as a change in the probability of establishment rather than as an automatic geographical expansion. A tick may be transported into a climatically suitable area but fail to establish because of inadequate hosts, unfavorable microhabitats, competition, or insufficient humidity. Conversely, a species may persist in an area that appears marginal at the regional scale by exploiting favorable microhabitats.

Recent North and West African literature further demonstrates that surveillance intensity is uneven. A 2025 systematic review compiling records from seven African countries identified 74 hard-tick species and 30 soft-tick species and showed that *Rhipicephalus* and *Hyalomma* were among the dominant genera. Although Libya was not one of the seven countries included in that particular compilation, the study highlights a broader regional problem: apparent absence may reflect limited sampling rather than true absence. This principle is important when interpreting tick distributions in Libya.

TICK FAUNA AND SEASONALITY IN LIBYA

Historical surveys demonstrate that Libya supports a diverse tick fauna. Gabaj, Awan, and Beesley reported thirteen ixodid species and two argasid species from 58 farms and 20,391 examined animals. *Hyalomma dromedarii* was particularly common on camels, *H. impeltatum* on sheep, and *H. excavatum* on cattle. These observations provide an important historical baseline for understanding tick distribution in Libya.

More recent work confirms substantial regional variation. In Tarhuna, northwestern Libya, 634 ticks were collected from 145 camels, sheep, and goats between August 2015 and May 2016. Four species were identified: *H. dromedarii*, *R. bursa*, *H. excavatum*, and *R. camicasi*. *H. dromedarii* accounted for 83.12% of the collected ticks, and the highest overall tick prevalence occurred in summer, whereas the lowest occurred in spring (Abdulsalam et al., 2022). These findings demonstrate that tick abundance differs among species and seasons and that host type is a major ecological factor.

The most geographically relevant recent evidence comes from Qarabulli in northwestern Libya. Shebani et al. (2024) examined 775 farm animals between July 2021 and June 2022 and collected 717 adult ticks. Eight hard-tick species were identified. *H. excavatum* was the most abundant species (41.00%), followed by *R. sanguineus* (23.43%), *H. dromedarii* (12.13%), *H. marginatum* (9.21%), *H. anatolicum* (8.51%), *R. annulatus* (5.30%), *H. rufipes* (0.28%), and *B. microplus* (0.14%). Tick occurrence varied among months, and January was the only month in which no ticks were collected.

These observations are relevant to climate-change research because they show that seasonal patterns already exist under current climatic conditions. However, they do not demonstrate that climate change caused the observed seasonal differences. Establishing a climate effect requires repeated measurements over multiple years, preferably with comparable sampling effort, climatic observations, host information, and spatial coordinates.

The Qarabulli study also illustrates the importance of distinguishing local ecological observations from national generalizations. The presence of *H. marginatum*, *H. dromedarii*, *H. anatolicum*, and several *Rhipicephalus* species in one region does not imply that the same relative abundance occurs in Aljabel Alghrbi. Local surveys remain necessary because livestock composition, vegetation, altitude, rainfall, and land use can differ considerably between regions.

TICK SPECIES OF PARTICULAR RELEVANCE TO ALJABEL ALGHRBI

Rhipicephalus and *Hyalomma* are among the most relevant genera when considering warm and semi-arid parts of Libya. *H. dromedarii* is strongly associated with camels but may occur on other hosts, while *H. excavatum* has been repeatedly associated with livestock. *R. sanguineus* is important because of its association with dogs and its role in transmission of spotted-fever group rickettsiae. *H. marginatum* is of particular interest because of its Mediterranean distribution and its recognized role in transmission of several pathogens, including Crimean–Congo hemorrhagic fever virus.

The exact species composition of Aljabel Alghrbi should not be inferred solely from studies in Qarabulli or Tarhuna. Nevertheless, these studies provide a rational basis for selecting candidate taxa for surveillance. A practical field program should include all adult and immature stages encountered and should record host species, sex,

developmental stage, collection location, and date. Morphological identification should be performed using validated keys, with molecular confirmation for specimens that are difficult to identify or belong to taxonomically challenging groups.

Species-level accuracy is particularly important for climate studies because different species can have different thermal and moisture requirements. Pooling all ticks into a single abundance measure may conceal opposing responses among taxa. For example, warming could increase activity of one species while excessive aridity reduces survival of another. Therefore, climate analyses should be performed at the species level whenever sample size permits.

CLIMATE CHANGE AND TICK-BORNE PATHOGEN TRANSMISSION

Climate can influence tick-borne disease risk through several interacting mechanisms. Warmer conditions may alter tick development and activity, host behavior, pathogen development, and the duration of contact between ticks and hosts. However, suitable climate does not necessarily result in increased disease transmission. Disease emergence depends on competent vectors, reservoir or amplification hosts, susceptible hosts, pathogen prevalence, and ecological connectivity.

Babesia, Anaplasma, and Rickettsia are among the pathogen groups relevant to the study context. In Africa, a large systematic review and meta-analysis demonstrated widespread detection of Anaplasmataceae, Rickettsiaceae, and Coxiellaceae in ticks and highlighted the importance of these organisms for livestock health. This regional evidence supports the value of pathogen surveillance in Libya, but it should not be interpreted as proof that a particular pathogen is present in Aljabel Alghrbi unless it is detected locally.

The relationship between tick abundance and pathogen prevalence is not necessarily positive. A rise in tick numbers could occur without an increase in infection prevalence, while a stable tick population could transmit more disease if pathogen prevalence, host infection, or host–tick contact changes. Consequently, climate-change studies should measure both vector abundance and pathogen infection status.

Molecular surveillance can substantially strengthen future studies in Libya. DNA or RNA-based assays can confirm tick species and detect pathogens that may be difficult to recognize morphologically. For Babesia, Anaplasma, and Rickettsia, molecular screening of individually identified ticks can be linked to species, life stage, host, location, and

climate variables. This approach would allow researchers to estimate pathogen prevalence and test whether environmental conditions are associated with infection risk. One Health is particularly appropriate for this problem because ticks connect human health, animal health, wildlife, and environmental conditions. Surveillance should therefore involve zoologists, parasitologists, veterinarians, epidemiologists, molecular biologists, and public-health authorities. The recent MENA-focused literature emphasizes integrated regional responses because climate change can affect tick ecology while livestock production, animal movement, land-use change, and human exposure simultaneously influence disease risk.

ENVIRONMENTAL AND LANDSCAPE FACTORS

Temperature and humidity should be interpreted in the context of landscape. Vegetation can provide shade and increase near-ground humidity, while bare soil and exposed surfaces may increase thermal and desiccation stress. Agricultural land, grazing areas, livestock shelters, hedgerows, and peri-domestic environments may therefore support different tick assemblages.

Land-use change can modify host density and movement. Expansion or intensification of agriculture may increase contact between livestock and wildlife, whereas changes in grazing practices can alter the frequency with which animals encounter questing ticks. Urban expansion may also create new interfaces between humans, dogs, livestock, and tick habitats. These processes can amplify or counteract the direct effects of climate.

Elevation should also be considered. Temperature generally decreases with elevation, while vegetation and moisture conditions may change substantially over relatively short distances. A regional climate dataset may therefore miss local conditions that are important to tick survival. Recording GPS coordinates, elevation, vegetation type, land cover, and distance to water or livestock shelters would improve ecological interpretation. Migratory birds and animal movements provide additional mechanisms for dispersal. Immature *Hyalomma* ticks can be transported by birds, and livestock movement can introduce ticks into new areas. Climate suitability may facilitate establishment after introduction, but dispersal and host availability determine whether introduced ticks become established populations. This interaction is particularly relevant to Mediterranean and North African regions.

RESULTS AND DISCUSSION

The synthesis of the available literature supports the central hypothesis that climate is an important determinant of tick ecology, but does not support a simple conclusion that an increase in temperature will lead to a uniform increase in tick populations. The strongest evidence suggests that temperature can accelerate evolution and modulate seasonal activity within species-specific physiological limits, while humidity, rainfall, vegetation, and host availability can facilitate or constrain these effects.

The published Libyan evidence reinforces the environmental context of the review. Tarhuna showed a marked dominance of *H. dromedari* and seasonal variation in tick prevalence, while qarabuli showed a wider population dominated by *H. rivatum* including *R. sanguineus* and *H. marginatum*. These differences between the nearby northwestern regions show that the composition of the local host and environmental conditions can form tick communities. They also illustrate why the only national prediction about the impact of climate change is scientifically weak.

The proposed link between warming and increased tick activity is therefore biologically plausible, especially for species adapted to warm environments. However, rising temperatures have increased the abundance of ticks and the transmission of parasites in the western gable the same caution applies to geographical expansion. Climate suitability models can identify areas where environmental conditions may become more favorable for certain species of ticks, but the actual establishment depends on host availability, dispersal, habitat structure, and other environmental factors. Evidence appears from *H. marginatum* that climate change can facilitate scale shifts, but climate is not necessarily the only causal driver.

The effects on tick-borne pathogens are similarly conditioned. A longer tick activity season can increase contact with the host and the chances of transmission, but the spread of pathogens must be measured directly. Thus, the most defensible conclusion of the western gable is that climate change may change the environmental conditions governing the risk of tick-borne diseases, while the magnitude and direction of the change has yet to be determined by local monitoring.

CONCLUSION

Climate change has the potential to alter tick development, seasonal activity, survival, and geographic suitability, thereby modifying the ecological conditions under which tick-borne pathogens are transmitted. The available literature indicates that these effects are complex and depend on interactions among temperature, humidity, precipitation, habitat, hosts, land use, and pathogen biology.

For Libya, recent studies demonstrate that tick communities can be diverse and strongly seasonal. Evidence from Qarabulli is particularly valuable because it provides recent local data on eight hard-tick species, while the Tarhuna study demonstrates strong species-specific and seasonal differences. These studies support the importance of local surveillance but do not by themselves establish a climate-change effect in Aljabel Alghrbi.

For Aljabel Alghrbi, the existing evidence therefore supports concern about possible climate-sensitive changes in tick ecology but remains insufficient to demonstrate that warming has already increased local tick abundance or pathogen transmission. A coordinated program of standardized tick surveillance, climatic monitoring, host and habitat assessment, molecular pathogen detection, and spatial analysis is required to generate reliable local evidence and guide public-health and veterinary interventions.

RECOMMENDATIONS

Develop continuous, standardized surveillance of tick species and seasonal activity in Aljabel Alghrbi.

Integrate climatic and ecological measurements into tick surveillance programs, including temperature, relative humidity, rainfall, vegetation, elevation, and land use.

Record host species and livestock management variables because host availability can strongly modify tick abundance independently of climate.

Use standardized morphological identification supported by molecular confirmation when species-level identification is uncertain.

Establish molecular surveillance for important tick-borne pathogens, including Babesia, Anaplasma, and Rickettsia, using validated assays.

Develop GIS-based risk maps after sufficient field data have been collected, and clearly distinguish habitat suitability from confirmed disease incidence.

Use longitudinal datasets to separate normal seasonal fluctuations from persistent climate-associated trends.

Strengthen collaboration among zoologists, parasitologists, epidemiologists, veterinarians, molecular biologists, and public-health authorities under a One Health framework.

Use locally generated evidence to develop targeted prevention and control strategies for livestock owners, veterinary services, and communities exposed to tick habitats.

Table 1. Conceptual pathways linking climate and tick ecology

Environmental factor	Potential mechanism	Expected ecological response	Important limitation
Temperature	Changes developmental rate, survival, questing activity, and pathogen development	Moderate warming may accelerate development or extend activity	Extreme heat can increase desiccation and mortality
Relative humidity	Controls water balance during off-host periods	Higher suitable humidity may improve survival	Regional humidity may not represent microhabitat humidity
Rainfall	Changes moisture, vegetation, and host behavior	Can improve suitable microhabitats or alter seasonal activity	Prolonged drought or extreme flooding may have different effects
Vegetation/land cover	Provides shade, shelter, and humid refugia	May increase local habitat suitability	Effects vary by tick species and landscape
Host availability	Determines blood-meal opportunities and dispersal	Higher host contact can support tick populations	Host abundance may change independently of climate
Animal movement	Introduces ticks to new areas	May facilitate establishment in climatically suitable sites	Introduction does not guarantee establishment

Source: Researcher's work

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