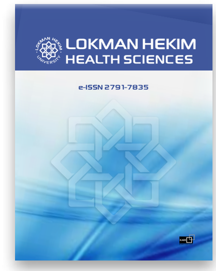
LOKMAN HEKIM HEALTH SCIENCES

DOI: 10.14744/lhhs.2026.00032
Lokman Hekim Health Sci 2026;6(3):531–544



lokmanhekimhs.com

REVIEW

The Potential Impact of Climate Change on Endemic *Bacillus anthracis* Infection in Türkiye*

Fatih Büyük[1], Callum Cooper[2], Özgür Çelebi[3], Yaren Ersoy[1], Mitat Şahin[1,4], Mehmet Doğanay[5], Les Baillie[6]

[1]Department of Microbiology, Faculty of Veterinary Medicine, Kafkas University, Kars, Türkiye
[2]School of Pharmacy and Pharmaceutical Sciences, Faculty of Health Sciences and Wellbeing, University of Sunderland, Sunderland, UK
[3]Department of Medical Microbiology, Faculty of Medicine, Kafkas University, Kars, Türkiye
[4]Department of Microbiology, Faculty of Veterinary Medicine, Kyrgyz-Turkish Manas University, Chingiz Aitmatov Campus, Djal, Bishkek, Kyrgyzstan
[5]Department of Infectious Diseases, Faculty of Medicine, Lokman Hekim University, Ankara, Türkiye
[6]Department of Microbiology, Faculty of Pharmacy and Pharmaceutical Sciences, Cardiff University, Cardiff, UK

Abstract

The impact of climate change is accelerating around the world, with effects ranging from increased global temperatures to changes in rainfall and drought patterns. For zoonotic diseases, there is an intrinsic link between the environment and incidence, with more extreme weather events leading to changes in vector behavior, changing epidemic dynamics over time. Within Türkiye, temperatures are predicted to increase by 5–6°C in inland regions and 4–5°C in coastal regions by 2100, whereas the level of precipitation is estimated to vary wildly depending on region. Anthrax is an endemic disease in several regions within Türkiye, capable of causing serious infections in both humans and animals and is caused by the Gram-positive, spore-forming organism *Bacillus anthracis*. Although reported case numbers are limited, *B. anthracis* is well adapted to survival in adverse environmental conditions by forming spores, enabling it to survive outside of a suitable host for prolonged periods of time, and as such, climate change presents an opportunity for the organism. In this review, the potential impact of climate change on *B. anthracis* will be evaluated.

Keywords: Anthrax; Climate change; Türkiye; Zoonotic diseases

Climate change is among the most pressing issues facing humanity today, with temperature rises of approximately 1°C since 1900 that are predicted to continue increasing unless substantial efforts are made to reduce carbon footprints. Rising temperatures have been linked to a wide range of adverse weather events, from increased rainfall and drought to more extreme events such as hurricanes and earthquakes. These climate-related changes can significantly affect both human and animal populations, leading to increased migration and shortages of food and other essential resources.[1]

*The editor did not contribute to the review process for this article; the process was conducted by associate editors and subject editors.

Cite this article as: *Büyük F, Cooper C, Çelebi O, Ersoy Y, Şahin M, Doğanay M, Baillie L. The Potential Impact of Climate Change on Endemic Bacillus anthracis Infection in Türkiye. Lokman Hekim Health Sci 2026;6(3):531–544.*

Correspondence: Fatih Büyük, M.D. Kafkas Üniversitesi Veteriner Fakültesi, Mikrobiyoloji Bölümü, Kars, Türkiye
E-mail: fatihbyk08@hotmail.com
Submitted: 11.09.2025 **Revised:** 18.09.2025 **Accepted:** 29.09.2025 **Available Online:** 13.05.2026

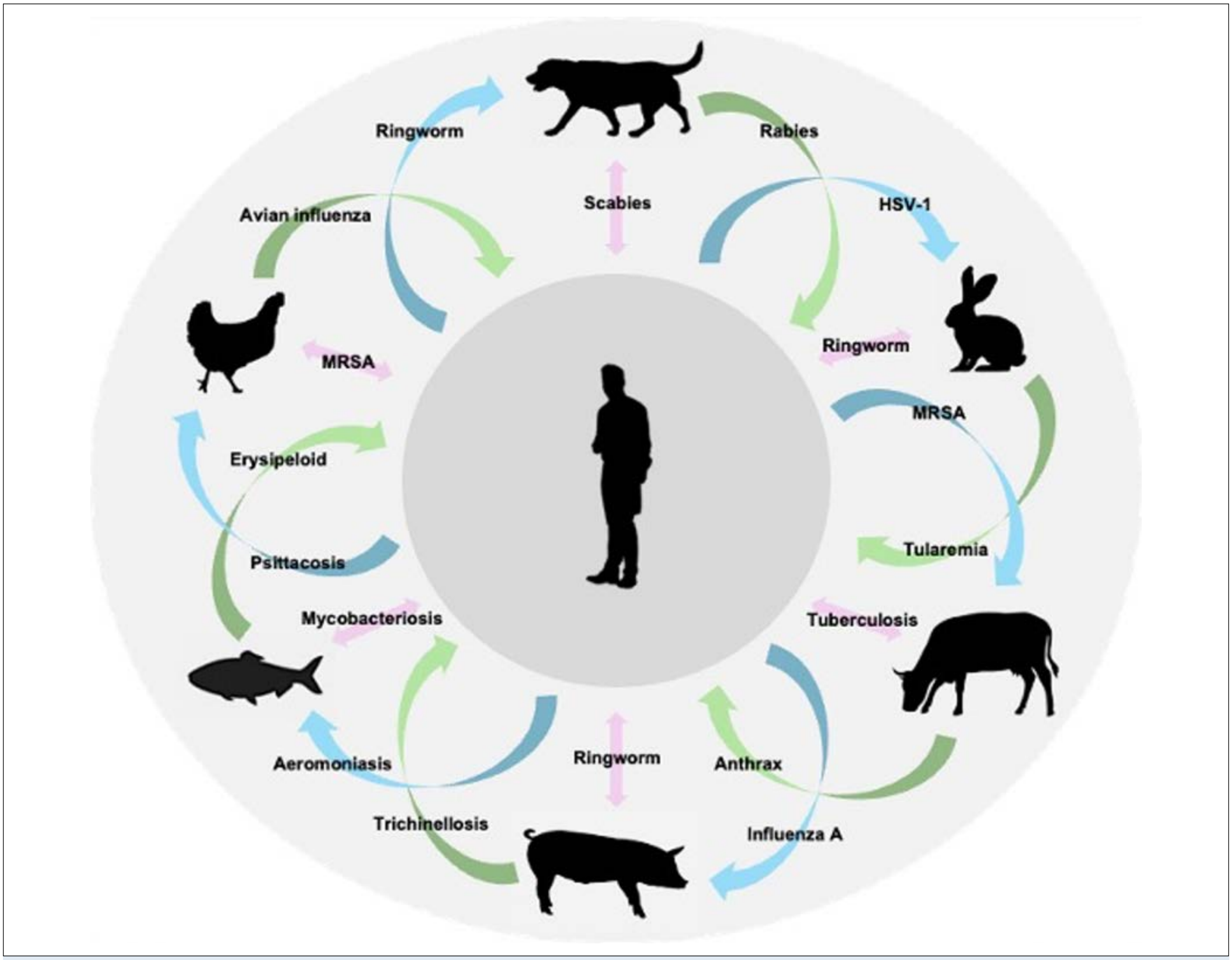


Figure 1. Classification of zoonotic infections based on the transmission from the source to the final host. Green curved arrows indicate diseases transmitted from animals to humans (anthropozoonosis), blue curved arrows indicate diseases transmitted from humans to animals (zooanthropozoonosis), and pink arrows indicate diseases transmitted in both directions (amphixenosis) (depicted by Fatih Büyük).[6]

Türkiye now accounts for approximately 1% of global emissions and has seen a steady increase in the total amount of greenhouse gases emitted since the 1980s. This increase has been accompanied by projected temperature increases of 5–6°C in inland regions and 4–5°C in coastal areas, compared to the average of 1961–1990.[2] An increasing temperature trend is projected alongside decreasing levels of precipitation until the end of the century using RCP4.5 and RCP8.5 climate scenarios in the HadGEM2-ES global climate model.[2–4] The different regions within Türkiye may vary in their susceptibility to adverse weather events, as well as the types of adverse weather effects they may experience, based on their local microclimate.[5]

Zoonoses are diseases transmitted between animals and humans, classified by direction as animal-to-human, human-to-animal, or both (Fig. 1).[6] More than 200 zoonotic diseases have been identified, with approximately 60% of all human pathogens and 75% of emerging infectious diseases believed to have originated from animals.[7] Several factors contribute to the emergence of zoonoses, including globalization, international trade, land-use changes, and climate change.[1] While such factors constantly fluctuate over time, zoonotic diseases often disproportionately impact groups from low and middle-income countries and globally are responsible for almost 2.5 billion cases of human infection and 2.7 million human deaths annually.[8]

Türkiye is a "biological crossroads" containing different ecosystems in which over 20,000 recorded animal species are found.[9] Türkiye, with its location between Europe, Asia, and the Middle East, creates a mosaic of microclimates.

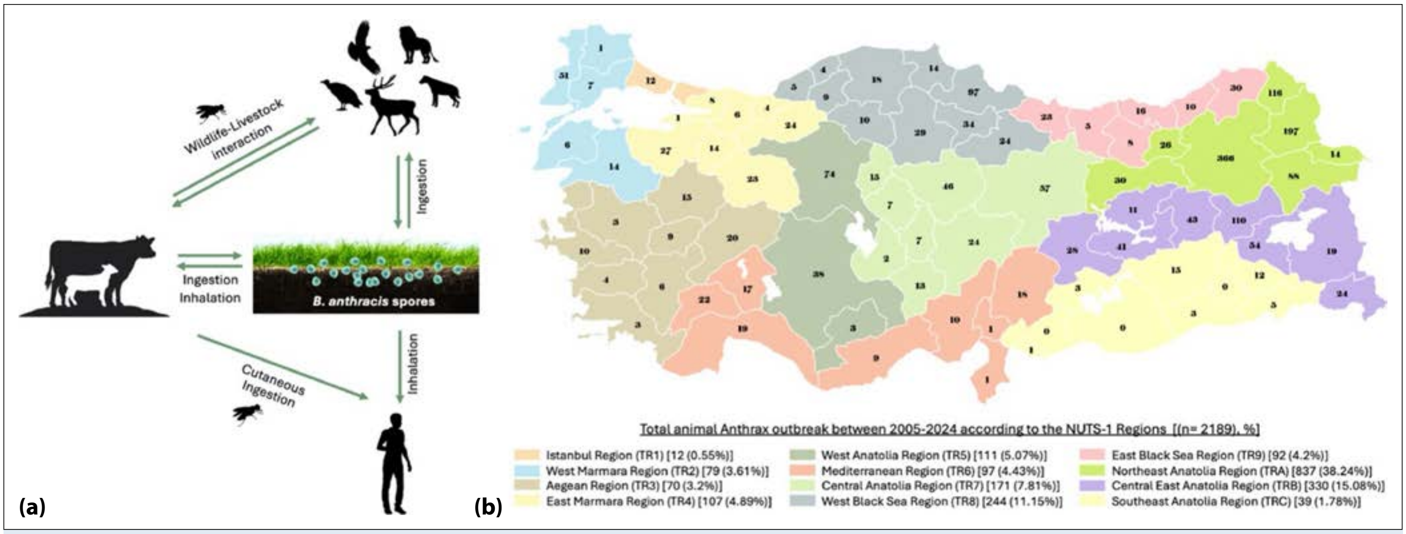


Figure 2. (a) Environmental persistence and transmission of *B. anthracis* (adapted from[12]) (Depicted by Fatih Büyük); **(b)** Geographic distribution of animal anthrax outbreaks by NUTS-1 regions in Türkiye (adapted from[15]).

These are localized climatic zones that differ from the surrounding broader regional climate, shaped by factors such as elevation, proximity to seas, vegetation, and human activity.[10] This range of ecosystems provides a wide range of potential wild and domesticated animal reservoirs for zoonotic infections and contains a number of regions that contain endemic zoonotic diseases (Table 1).[11]

The current review focuses on the potential impact of climate change on endemic *Bacillus anthracis* within Türkiye. To prepare the article, a structured literature search was performed using the keywords "climate change," "zoonotic diseases," "anthrax," "*Bacillus anthracis*" and "Türkiye" across PubMed, Web of Science, and the official websites of the Turkish Ministry of Health, the Turkish Ministry of Agriculture and Forestry, and the World Health Organization. The search was limited to publications from 2000 to 2025 and included studies in English and Turkish that focused on Türkiye or presented relevant regional data. Gray literature and national surveillance data were also reviewed to provide local context. Articles without empirical findings, duplicates, or those not addressing the intersection of climate change and anthrax were excluded.

Current Perspectives on *B. anthracis* in Türkiye

B. anthracis is a Gram-positive, spore-forming microorganism that causes both human and animal anthrax,[12] which is estimated to have cost the Turkish economy approximately $3.8 m in purchasing power parity in 2018 alone.[13] Due to its ability to form spores, it can survive in the environment for prolonged periods, remaining dormant until a suitable host is infected, at which point it transforms into vegetative cells and proliferates (Fig. 2a). Human infection usually occurs as a result of contact with contaminated environments, animals, or animal products.[12]

Anthrax is a sporadic disease; however, based on its spatiotemporal distribution, it is classified into enzootic, hyperendemic, or sporadic anthrax ecological regions.[14] In this study, we adopted relative endemicity thresholds based on the reported case rate per region in Türkiye; regions accounting for more than 40% of total national cases were considered hyperendemic (none at present), 10–40% were enzootic (TRA, TRB), and <10% were sporadic (the other NUTS-1 regions). These definitions are consistent with those previously applied in regional epidemiological contexts. Based on these thresholds, there are no hyperendemic areas for *B. anthracis* in Türkiye; however, the cumulative prevalence in the Northeast Anatolia Region (TRA) and the Central East Anatolia Region (TRB) has brought the Eastern Anatolia region within these limits.

Between 2005 and 2024, of the 2189 animal anthrax outbreaks reported in Türkiye, 38.24% occurred in the Northeast Anatolia Region and 15.08% in the Central East Anatolia Region.[15] These regions accounted for the highest incidence rates for the 1.080 human anthrax cases observed between 2009 and 2018, making them the regions with the highest incidence rates.[16] These regions also coincide with regions where zoonotic transmission and human–animal interaction are high (Fig. 2a, b). These include Kars, Erzurum, Ardahan, and Muş, which are not only agriculturally active but also climatically vulnerable – experiencing seasonal snowmelt that may facilitate spore reactivation and surface exposure. In TR5 and TR7 regions,

Table 1. Zoonotic disease risks in relation to regional and microclimatic variation in Türkiye: A NUTS-based spatial analysis (information obtained from[11,42])

Region	Region (NUTS-1/ NUTS-2)	Climate type	Microclimate features (NUTS-3)	Zoonoses at risk	Probability of anthrax occurrence	Influencing local factors
Marmara	Istanbul Region (TR1) • Istanbul Subregion (TR10) West Marmara Region (TR2) • Tekirdağ (TR21) • Balikesir Subregion (TR22) East Marmara Region (TR4) • Bursa Subregion (TR41) • Kocaeli Subregion (TR42)	Mixed (Mediterranean, oceanic, and continental)	• Urban heat islands are strong in Istanbul (TR100) and Bursa (TR411). • The Sea of Marmara moderates the climate in coastal zones (TR100, TR421, TR425, TR411, TR221, TR211, and TR222). • Forested uplands (e.g., Yalova [TR425] and Bilecik [TR413]) show cooler, more humid microclimates.	West Nile Virus, Leptospirosis, Salmonella, Anthrax	Low-Medium	There may be risks in areas where rural animal husbandry is practiced. • Rural animal husbandry practices • Increased urbanization • Environmental conditions • Inadequate carcass disposal practices • Limited awareness or education
Aegean	Aegean Region (TR3) • İzmir Subregion (TR31) • Aydin Subregion (TR32) • Manisa Subregion (TR33)	Transitional Mediterranean–semi-arid inland	• Coastal areas (TR310, TR321, TR323, and TR221) experience humid, mild winters. • Inland parts like Uşak (TR334) or Afyon (TR332) show more continental features-colder winters, hotter summers. • The Meander River basin (TR321, TR322, TR332, and TR334) fosters unique agricultural microclimates.	West Nile Virus, Brucellosis, Anthrax, Leishmaniasis, Toxoplasmosis	Medium	The risk may increase in rural areas where livestock farming is practiced. • Inadequate vaccination coverage and carcass disposal practices • Lack of veterinary infrastructure • Increased interaction between wildlife and livestock • Limited awareness or education
Central Anatolia	West Anatolia Region (TR5) • Ankara Subregion (TR51) • Konya Subregion (TR52) Central Anatolia Region (TR7) • Kirikkale Subregion (TR71) • Kayseri Subregion (TR72)	Semi-arid continental	• Large daily temperature variations. • Urban areas (e.g., Ankara [TR510], Konya [TR521]) show strong urban heat island (UHI) effects. • Irrigated agricultural zones (e.g., Konya Plain [TR521, TR522, TR712, TR713, TR714, and TR721]) create localized humid zones compared to the surrounding dry steppe.	Tularemia, Brucellosis, Q Fever, Anthrax, Hantavirus, Avian Influenza	Extremely high	Spores may come to the surface, contact between animals increases, and the risk of infection rises with the shrinking of pastures. • Soil disturbance due to overgrazing or land degradation • Reduced pasture availability, higher animal density, and contact between animals • Increased contact with contaminated soil or vegetation

Table 1 (cont). Zoonotic disease risks in relation to regional and microclimatic variation in Türkiye: A NUTS-based spatial analysis (information obtained from[11,42])

Region	Region (NUTS-1/NUTS-2)	Climate type	Microclimate features (NUTS-3)	Zoonoses at risk	Probability of anthrax occurrence	Influencing local factors
Eastern Anatolia	Northeast Anatolia Region (TRA) • Erzurum Subregion (TRA1) • Ağrı Subregion (TRA2) Central East Anatolia Region (TRB) • Malatya Subregion (TRB1) • Van Subregion (TRB2)	Harsh continental	• High elevation (average >1500 m) leads to cold, subalpine microclimates, especially in Kars (TRA22), Erzurum (TRA11), and Ardahan (TRA24). • Snow cover persists longer, influencing local hydrology and agriculture. • Valleys may exhibit slightly warmer, more sheltered microclimates.	Tularemia, Anthrax, Crimean-Congo Hemorrhagic Fever, Hantavirus	High	Sudden rainfall can cause spores to surface, continuing the cycle of traditional animal husbandry. • May risk of contamination of soil with spores and exposure of animals • Traditional livestock farming practices • Animals grazing in contaminated areas after rainfall • Limited adaptation to climate variability
Southeastern Anatolia	Southeast Anatolia Region (TRC) • Gaziantep Subregion (TRC1) • Şanlıurfa Subregion (TRC2) • Mardin Subregion (TRC3)	Hot semi-arid	• Very hot summers (up to 45°C), with mild winters. • The GAP irrigation project has introduced local humidity and vegetation changes, altering microclimates in areas like Şanlıurfa (TRC21) and Diyarbakır (TRC22). • Mountainous zones near Siirt (TRC34) and Hakkâri (TRB24) are cooler and wetter.	Crimean-Congo Hemorrhagic Fever, Leishmaniasis, Hydatid Disease, Brucellosis, Tuberculosis, Anthrax	Medium–High	New moist areas can activate anthrax, and spread is possible through small livestock farming. • Formation of new moist areas • Activation of dormant *B. anthracis* spores • Small-scale or traditional livestock farming practices
MeditErranean	Mediterranean Region (TR6) • Antalya Subregion (TR61) • Adana Subregion (TR62) • Hatay Subregion (TR63)	Hot-summer Mediterranean	• Hot, dry summers; mild, wet winters. • Coastal plains (e.g., Antalya [TR611], Mersin [TR622]) are warmer and more humid than upland areas such as Isparta (TR612) and Burdur (TR613). • Sea breezes and topography (e.g., Taurus Mountains [TR611, TR622, TR621, TR631, TR612, TR613, and TR323]) shape local climates.	Leishmaniasis, West Nile Virus, Brucellosis, Anthrax	Medium	Temperature increases may pose risks in new areas, but humid climates may mitigate the risk • Expand the potential range of anthrax outbreaks • Drier soils may favor spore longevity • High humidity levels may reduce spore survival
Black Sea	West Black Sea Region (TR8) • Zonguldak Subregion (TR81) • Kastamonu Subregion (TR82) • Samsun Subregion (TR83) East Black Sea Region (TR9) • Trabzon Subregion (TR90)	Humid oceanic	• One of the most uniformly humid areas of Türkiye, especially in the eastern Black Sea (Rize [TR904], Artvin [TR905]). • Dense forest cover regulates temperature and humidity. • Inland microclimates become drier and more continental beyond the coastal mountains.	Leptospirosis, Anthrax, Hantavirus, Lyme Disease, Salmonella	Low	The likelihood of flooding is low; however, excessive rainfall may pose a local risk. • Excessive rainfall may saturate the soil, bringing *B. anthracis* spores to the surface • Temporary water accumulation in low-lying areas may concentrate livestock activity • Localized microflooding may disrupt spore-containing soil layers

where human cases are endemic and animal outbreaks are sporadic, increasing temperatures and droughts associated with climate change could bring spores to the surface and increase contact between animals due to shrinking pastures, thereby raising the risk of infection. Similarly, the West Black Sea Region (TR8) and the East Black Sea Region (TR9), where meso-endemic (11.15%) or hypo-endemic (4.2%) outbreaks have been observed,[15] may be increasingly affected by sudden floods and irregular rainfall patterns (Table 1).

The prevalence of anthrax in Türkiye is therefore closely related to climatic patterns, microclimatic conditions, and broader environmental factors. While the risk remains highest in arid and continental climate regions, particularly during the summer, emerging evidence suggests that the activation cycle of *B. anthracis* spores may shift in response to climate change.[17] Consequently, there is a growing concern that anthrax may expand into previously unaffected regions due to increased soil disturbance, water contamination, and altered ecological balances. These changing environmental dynamics underscore the need to re-evaluate anthrax control strategies not only in historically endemic zones but also in regions undergoing climate-related transitions, which will be discussed further in the following section.

The Potential Impact of Climate Change on *B. anthracis* in Türkiye

Anthrax is recognized as a global threat affecting wildlife, livestock, and human health. The environmental spread of *B. anthracis* or its spores is influenced by a range of biotic (e.g., insects, birds, and animals), abiotic (e.g., climate change, water, and soil), and anthropogenic (e.g., human activities, poverty, and conflict) factors. Climate change alters environmental variables such as precipitation, cloud cover, and wind speed, with even slight increases –such as 1 mm of rainfall, 1 h of daily cloud cover, or 1 knot of wind speed being associated with rises in anthrax outbreaks by 9.5, 36.7, and 107 times, respectively.[18] Moreover, climate change may shift the geographic distribution of anthrax by directly or indirectly affecting the underlying biotic and abiotic conditions that determine pathogen persistence.[19]

Climate change is increasingly recognized as a key driver of infectious disease dynamics, particularly for environmentally persistent pathogens such as *B. anthracis*. Climatic and ecological changes – such as rising temperatures, altered precipitation regimes, thawing permafrost, and shifts in vegetation cover can significantly impact the environmental persistence, reactivation, and transmission pathways of anthrax spores. These are not isolated factors but interact with local ecological and agricultural practices, increasing the risk of exposure to animals and humans. In Türkiye, diverse climatic zones are exposed to varying climate-related pressures, resulting in region-specific risks. The following section outlines how these multifactorial influences shape the epidemiology of anthrax in different parts of the country.

Increased Temperature

Rising ambient and soil temperatures can enhance *B. anthracis* spore viability and accelerate the decomposition of infected carcasses, facilitating the release and reactivation of spores into the environment.[19] In Türkiye, such effects are particularly relevant in Eastern and Central Anatolia, as well as Southeastern Anatolia (NUTS regions: TRA, TRC, TR7), where long, dry summers and continental climates prevail. These areas have historically reported higher anthrax incidence and are increasingly vulnerable to climate-induced ecological shifts (Table 1, 2).

From an environmental standpoint, elevated temperatures lead to greater soil desiccation, which may promote the aerosolization of dormant spores. This process not only increases environmental contamination but may also shift the dominant route of transmission – from the more common gastrointestinal form associated with ingestion of contaminated materials to inhalational anthrax, which carries a higher mortality risk and presents greater public health concerns. As such, it may be possible for spores to spread to areas far from the original contamination sites located throughout Türkiye, thereby increasing the likelihood of exposure to humans and animals.

Furthermore, increased temperatures may extend the active period of vectors, as discussed in the vector section. Prolonged warm seasons also impact vegetation cover and animal grazing patterns, causing livestock to forage closer to the soil where spores may concentrate during dry spells.[20] This behavioral change further heightens contact between animals and contaminated substrates. It is especially relevant to the Mediterranean (TR6), the West Black Sea (TR8), and the East Black Sea Region (TR9), as well as the Central Anatolia (TR7) and the Southeastern Anatolia Region (TRC) (Table 1, 2).

Permafrost and Snow Melting

Active layers (soil zones above the permafrost) serve as long-term reservoirs for infected animal carcasses and

Table 2. Potential impacts of climate change on anthrax transmission dynamics in Türkiye: Mechanisms and regional vulnerabilities

Climate change factor	Mechanism of influence	Potential impact on anthrax transmission	Regions in Türkiye affected
Increased temperature	Increased temperature enhances spore viability and accelerates carcass decomposition, while elevated soil temperatures may further facilitate the reactivation of *B. anthracis* spores.	Increases spore exposure and transmission risk.	Eastern and Central Anatolia, Southeastern Anatolia (TRA, TRC, and TR7)
Permafrost thaw/ freeze-thaw cycles	Thawing of periglacial or high-altitude soils can reactivate dormant spores, as frozen ground releases old animal carcasses and previously buried *B. anthracis* spores to the surface.	May trigger the re-emergence of anthrax in historically inactive areas and increase the risk of new outbreaks.	Eastern Black Sea Mountains, Taurus Mountains, volcanic cones (TRA, TRC, and TR7)
Heavy rainfall and flooding	Heavy rainfall and flooding can mobilize spores from contaminated soil into water systems and grazing areas, whereas extreme weather events may force animals to congregate in these high-risk zones, increasing the likelihood of transmission.	As animals and humans are increasingly exposed to contaminated environments, the chain of infection can accelerate.	West and East Black Sea, parts of Marmara and Mediterranean (TRA, TR1, TR6, TR8)
Drought and soil degradation	Drought and soil degradation increase soil spore concentration, while limited water sources and extreme weather events cause livestock to congregate densely, enhancing the risk of transmission.	Increased contact between animals and contaminated soil can lead to an accelerated chain of infection.	Central Anatolia, Southeastern Anatolia (TRC, TR7)
Snowmelt events	Washes spores from buried carcasses to the surface.	Leads to localized outbreaks during spring/summer	Kars, Erzurum, Ardahan, Muş (TRA and TRB)
Changes in vegetation patterns	Alters grazing routes and habitat use. Altered pathogen distribution and host behavior can increase exposure and burden immune systems.	May bring susceptible animals into contact with contaminated sites. May weaken or overwhelm immune tolerance, thereby increasing the risk of anthrax	Nationwide, particularly rural pasturelands (TRA, TRC, TR1, TR3, TR6, TR7, TR8, and TR9)
Increased insect activity (e.g., biting flies)	Warmer, wetter conditions boost vector populations.	Possible mechanical transmission, especially in outbreak zones.	Regions with livestock density and wet summers (TR1, TR6, TR8, and TR9)
Animal migrations and dispersal	Alters wildlife and livestock movement patterns and habitat in search of resources.	Anthrax can be transported to new areas.	Steppe zones, transhumance routes, and drought-affected regions (TRA, TRC, TR3, and TR7)
Increased human–animal interaction	With the expansion of agricultural areas, human activity increases in risky areas.	Raises the likelihood of zoonotic spillover and human infection.	Rural areas with expanding agricultural activity (TRA, TRC, TR1, TR3, TR6, and TR7)
Impact on Health Infrastructure	Climate change can strain healthcare systems.	Delays in diagnosis, surveillance, and response capacity.	Vulnerable and under-resourced rural regions (TRA, TRC, TR7, and TR9)

anthrax spores, potentially facilitating disease transmission during seasonal thawing. Epidemiological models adapted to Arctic conditions indicate that the deepening of these active layers – particularly in unusually warm years – significantly increases the risk of anthrax outbreaks. Indeed, the cause of a recent anthrax outbreak in reindeer in Siberia was reported to be related to the presence of infected carcass spores released from permafrost thawing from active layers due to rising temperatures.[21]

Although there are no classical permafrost zones in Türkiye, localized periglacial conditions exist in regions such as the Eastern Black Sea Mountains, the Taurus Mountains, and high volcanic cones,[22] where freeze-thaw processes may pose future risks of spore release.

Figure 3. Examples of improper anthrax-contaminated waste management practices in endemic regions of Türkiye. **(a)** A potentially infected piece of cardboard exposed to open air; **(b)** A contaminated cattle hide placed on a barn roof; **(c)** A decomposing carcass in a public dump site. These images reflect weak biosecurity infrastructure and emphasize the risk of environmental contamination in the absence of comprehensive control measures, particularly under climate-stressed conditions. (All photos were obtained from the collection of Mitat Şahin [Kafkas University / Kyrgyz-Turkish Manas University], Özgür Çelebi [Kafkas University], and Fatih Büyük [Kafkas University]).

Even under current climatic conditions, other factors may be contributing to the formation of anthrax hotspots in these colder areas. Provinces such as Kars, Ardahan, Erzurum, Ankara, Konya, and Kayseri (NUTS regions: TRA, TR5, and TR7) are characterized by cold, arid, or increasingly drought-prone climates, limited resources, harsh environmental constraints and insufficient implementation of biosecurity measures (e.g., proper carcass disposal or disinfection protocols per[23]) may lead to improper handling of infected animals or materials. Such practices, exemplified in Fig. 3a–c, can contribute to persistent environmental contamination[24] and facilitate future outbreaks.

Higher Rainfall and Flooding

Heavy spring rains followed by hot, dry summers often result in localized flooding and are increasingly associated with outbreaks of animal anthrax. This association is now considered part of current perspectives on the ecological effects of climate change on zoonotic disease patterns.[25] Excessive rainfall, flotation, and flooding can carry *B. anthracis* spores into the rhizosphere of the soil or local watering holes, where the spores can germinate and multiply.[26] This period of abundant water, followed by dry weather, will lead to water evaporation, which will concentrate the spores and increase the infective dose levels.[27]

Germinating spores may facilitate the transfer of genetic material or the emergence of cross-species variants.[26] While these processes occur under current conditions, emerging evidence suggests that climate change – especially through drought stress, altered precipitation patterns, and increased environmental disturbance – may accelerate horizontal gene transfer and microbial evolution in soil ecosystems (e.g., enhanced genetic exchange under drought conditions)[28] and create opportunities for cross-over variants such as those observed in the *Bacillus cereus* group.[27] These mutant bacteria may evolve to pathogenicity and cause clinical pictures that do not correspond to classical anthrax, or they may have the potential to be used as biological agents instead of *B. anthracis*.[29] Given that a cow dying of anthrax sheds approximately 1012 spores, soil containing untreated or flood-prone spore-laden animal burials (Fig. 4a–c) – which are common in Türkiye, particularly in the Eastern Anatolia Region (TRA, TRB) – constitutes not only a persistent infection source but also a genetic reservoir of *B. anthracis* that may be diagnostically overlooked.

Currently, such improper carcass disposal contributes to the formation of endemic hotspots. However, under projected climate change scenarios, increasing flood events, soil degradation, and competition for grazing land may bring animals and humans into closer contact with these contaminated sites. Without improved disposal practices and biosecurity measures, these conditions could promote the expansion of anthrax-endemic areas and potentially support the evolution or emergence of novel or resistant *B. anthracis* strains. Furthermore, surface runoff or superficial flooding caused by intense rainfall on sloped or impermeable surfaces – referred to as pluvial flooding – can transport *B. anthracis* spores over short or long distances from contaminated sites, leading to the formation of new hotspots.[24] This risk is not limited to rural or grazing areas; with increasing urbanization, impermeable urban surfaces can exacerbate runoff dynamics, potentially facilitating the spread of spores into peri-urban environments where human–animal interactions may also occur.

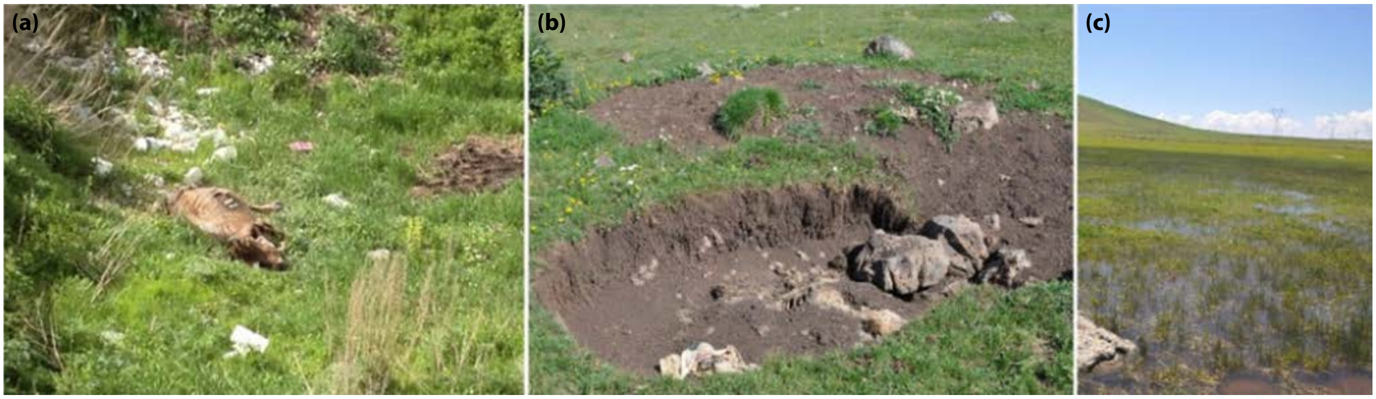


Figure 4. Potential climate-sensitive sources of anthrax contamination triggered by flooding or surface runoff. **(a)** A large, shallow burial pit containing an untreated anthrax-infected cattle carcass, vulnerable to spore flotation during heavy rainfall; **(b)** A superficially buried, four-cornered anthrax grave with minimal protective coverage, exposed to pluvial flooding and erosion; **(c)** A contaminated lowland area visibly impacted by recent rain-induced surface water movement, representing a potential dispersal zone for *B. anthracis* spores. (All photos were obtained from the collection of Mitat Şahin [Kafkas University / Kyrgyz-Turkish Manas University], Özgür Çelebi [Kafkas University], and Fatih Büyük [Kafkas University]).

Increasing evidence suggests that flooding and other hydrological events linked to climate change may elevate the risk of anthrax outbreaks by mobilizing *B. anthracis* spores from contaminated soils. This risk is particularly relevant in Türkiye, where a significant number of settlements – including those in the Istanbul Region (TR1), the West Marmara Region (TR2), the East Marmara Region (TR4), the West Black Sea Region (TR8), and the East Black Sea Region (TR9) – are located on geomorphologically sensitive landscapes such as floodplains, dry riverbeds, and alluvial soils. These low-lying areas are especially vulnerable to increased precipitation and surface water accumulation, which may facilitate the horizontal spread of spores.

For instance, the most recent major flooding event occurred in the Western Black Sea Region (TR8) in 2021. Although no direct anthrax cases were reported in connection with the floods,[30] the potential for future outbreaks remains high due to the ecological vulnerabilities of such regions. In addition, in the Northeast Anatolia Region (TRA) and the Central East Anatolia Region (TRB), climatic shifts are expected to increase freeze-thaw cycles and snowmelt during spring (Table 1, 2). These processes may lead to water table fluctuations and facilitate vertical movement of *B. anthracis* spores to the surface, thereby expanding the risk of soil contamination and disease transmission.

Animal Migrations, Habitat Changes, and Human–Animal Interactions

The current geographical distribution of *B. anthracis* has been shaped as a result of long-term activities such as historical human settlements, trade routes, and animal migrations.[31] However, this distribution is now being reshaped by climate change. Climate change redefines not only environmental boundaries but also alters epidemiological boundaries, significantly impacting the dynamics of zoonotic disease spread. Zoonotic diseases such as anthrax have the potential to emerge in new geographical areas as a result of changing animal behavior, habitat shifts, and increased human–animal interactions due to climate change. In particular, environmental variables such as increasing temperatures, decreasing soil moisture, and thawing of permafrost regions facilitate conditions in which *B. anthracis* spores can survive in soil, potentially causing previously inactive spores to become pathogenic again.[17]

Climate change is also causing many animal species to change their habitats. Rising temperatures and droughts are forcing species to migrate to cooler or more ecologically favorable regions – often to the north or higher altitudes. Changes in food and water resources are reshaping these migration routes and exposing animals to different ecosystems and thus new microbial environments.[31] Environmental factors, alongside host behaviors, shape exposure levels to *B. anthracis* and immune responses in host species. Variables such as vegetation, rainfall patterns, and forage availability influence exposure frequency and dose, causing variations in host immune responses.[32] Climate-related environmental changes may disrupt this balance. Climatic events like sudden rainfall, drought, or temperature fluctuations can alter pathogen distribution and host behavior, increasing exposure and burdening immune systems. This may weaken or overwhelm immune tolerance, thereby increasing the risk of anthrax. Thus, climate-induced changes can complicate disease dynamics by affecting both pathogen ecology and host immunity.

Prolonged droughts in the Mediterranean Region (TR6) and the Southeastern Anatolia Region (TRC) of Türkiye may force wildlife to migrate to higher and cooler areas in the Northeastern Anatolia Region (TRA) and the West Black Sea Region (TR8), which maintain relatively stable water and vegetation profiles. Similarly, in the West Anatolia Region (TR5), where intensive land use and desertification are prevalent, a gradual movement of species toward the Central Anatolia Region (TR7) and the East Marmara Regions (TR4) may be observed, potentially altering interregional ecological interactions. These changes may increase the likelihood of contact between species, as well as the risk of exposure to new microbial environments and zoonotic pathogens such as *B. anthracis*.

In biogeographically strategically located countries such as Türkiye, both local climate change (Table 1) and the intersection of African-Central Asian wildlife migration routes may lead to the emergence of new infectious disease risks. Climate change is driving wild animals to move increasingly toward urban areas in search of food and water. This will increase their contact with contaminated environments such as garbage dumps or shallowly buried animal graves (Fig. 3c, 4a, b), which may increase the risk of anthrax transmission and may even increase the risk of human–animal conflict. This risk is not uniform across the country but varies by region. For example, urban expansion in the Istanbul Region (TR1) and the West Marmara Region (TR2) is extending into surrounding forested areas, thereby bringing wildlife into closer proximity with human settlements. In contrast, intensifying drought conditions in the Mediterranean Region (TR6) and the Southeast Anatolia Region (TRC) are reducing access to natural water sources, pushing wild animals toward irrigated agricultural areas or urban peripheries. Furthermore, in the Northeast Anatolia Region (TRA) and the Central East Anatolia Region (TRB), the risk of exposure may increase due to both local and migratory animals passing through old burial grounds or contaminated pastures (Fig. 4a–c).

Changes in Vegetation Cover

Climate change-induced changes in vegetation cover – such as the decline of grasslands, changes in plant species, and deterioration of grassland quality – may alter the grazing behavior and migration routes of both farm animals and wild herbivores across Türkiye.[9] These ecological changes may increase the likelihood of animals entering areas where *B. anthracis* spores, which may be dormant in the soil, are present. This risk is particularly likely in the Northeast Anatolia Region (TRA) and the Southeast Anatolia Region (TRC). Similarly, increased drought and land use pressure in the Central Anatolia Region (TR7) and the West Black Sea Region (TR8) may push grazing activities into marginal lands, increasing the likelihood of exposure to contaminated soil. In addition, in regions such as the Istanbul Region (TR1), the Aegean Region (TR3), and the Mediterranean Region (TR6), the urban-rural interface is expanding toward traditional grazing areas, increasing animal density and interspecies interactions. These overlapping pressures may facilitate the spread of anthrax not only among livestock populations but also across administrative boundaries through changing migration routes. Therefore, changes in vegetation cover may function as a critical ecological factor in the reactivation and spread of anthrax across Türkiye's diverse biogeographic landscapes.

Vectors

Several insect species, including biting flies (*Tabanus* and *Stomoxys*) and non-biting blowflies (*Calliphoridae*), have been experimentally and historically associated with the mechanical transmission of anthrax. Mosquitoes (*Aedes* spp.) have also shown potential in laboratory settings, but their role in natural outbreaks remains unclear.[12]

In Türkiye, where diverse climatic and ecological conditions support the proliferation of vector species such as mosquitoes and ticks,[33] the potential for vector-borne anthrax transmission is theoretically present but epidemiologically marginal. Meteorological factors are thought to contribute to the spread of anthrax by facilitating the development of biting flies.[21] The risk becomes more relevant only when seasonal population peaks of vectors coincide with the presence of *B. anthracis*-infected animal carcasses, which may occasionally occur in endemic zones. This convergence is more likely in rural and livestock-dense regions such as the Southeast Anatolia (TRC), the Central Anatolia Region (TR7), and the Eastern Anatolia (TRA, TRB), where animal deaths may go unnoticed or improper carcass disposal practices prevail. However, current evidence does not support the long-distance spread of anthrax spores through flies or ticks; their role is limited to localized amplification under specific environmental conditions.[12] Thus, although Türkiye's regions such as the Mediterranean Region (TR6) and the Black Sea Region (TR8, TR9) offer suitable habitats for mosquito development, the overall contribution of arthropod vectors to anthrax transmission remains low. Consequently, while climate-induced increases in vector populations may pose theoretical risks, these are insufficient on their own to drive anthrax outbreaks across Türkiye's NUTS regions without concurrent factors such as carcass exposure or endemic presence of the pathogen.

Successive Effects: Migration and Disasters

Although anthrax is not categorized as an epidemic disease with direct devastating effects such as cholera, tetanus, rabies, and typhoid, it is an important zoonotic infection whose incidence can increase in situations of environmental stress, disruptions in health systems, and mass mobility. The spread of anthrax and similar diseases can accelerate, particularly during societal breakdowns such as war, economic crisis, and natural disasters. Such crises may be expected to become more frequent and severe with climate change. The risk of anthrax reemerging in Türkiye varies according to the NUTS regions shaped by climate-induced migration, disaster exposure, and systemic health vulnerabilities. Although Türkiye is not currently in an active war zone, the Istanbul Region (TR1), the Southeast Anatolia Region (TRC), and the Mediterranean Region (TR6) have become important transit and shelter areas for migrants. Factors such as drought, floods, and agricultural collapse due to climate change are also expected to increase these migration movements. This creates not only a demographic but also a health-related burden.

The re-emergence of infections such as multidrug-resistant bacterial infections, tuberculosis, measles, leishmaniasis, and hepatitis A in migrant communities poses risks to both the local population and health systems.[34] Deteriorating living and hygiene conditions due to climate change are a major risk factor for the spread of infections such as anthrax, especially those transmitted through the skin. In migration settings where acute wound care and preventive health services are inadequate, the risk of transmission through contaminated animal products or environmental contact increases. The case of Türkiye, accused of being an accidental source of a strain of anthrax through heroin use, a new route of transmission for anthrax, and later cleared only as a transit country,[35] is another clear example of the risk of anthrax for migrants or refugees and the damage to the country's reputation. In addition, in agricultural transition zones such as the West Anatolia Region (TR5) and the Mediterranean Region (TR6), where mobile populations intersect and animal disease surveillance is inadequate, and in the Southeast Anatolia Region (TRC) and the Central East Anatolia Region (TRB), which face socioeconomic vulnerability and historical anthrax endemicity, due to their proximity to migration routes and limited veterinary infrastructure, may facilitate the emergence or undetection of not only anthrax but also other transboundary diseases such as the SAT-2 variant of foot-and-mouth disease.[36]

While no direct link has been established between earthquakes and natural anthrax outbreaks in the literature to date, seismic events may act as secondary triggers for environmental zoonotic disease risks under certain ecological and infrastructural conditions. For instance, the 2023 Kahramanmaraş Earthquake, which affected 11 provinces in the Southeastern Anatolia (TRC), Central Anatolia (TRB), and Eastern Anatolia (TRA) regions, may reveal the potential for indirect but significant risks related to environmental zoonotic diseases such as anthrax. These risks could be exacerbated by earthquake-induced soil degradation, exposing contaminated animal burial sites and creating alkaline soil conditions conducive to the survival of *B. anthracis* spores, particularly in areas rich in calcium, magnesium, and iron. The long-standing practice of shallow or unmarked animal burial in rural areas of these regions (according to Turkish legislation[23]) could further exacerbate this threat. These indirect risks may be amplified when coupled with climate stressors such as rising temperatures, droughts, or flooding, all of which alter soil microbial dynamics and ecosystem balance. Moreover, post-disaster displacement and migration into already climate-stressed NUTS regions (TRB, TRC, and TR6) may further strain health infrastructure and complicate surveillance efforts for cutaneous anthrax and other zoonotic infections. In contrast, regions such as the West Anatolia Region (TR5) and the Mediterranean Region (TR6), which are less affected by seismic activity, face higher risks due to secondary effects such as increased climate migration and ecological pressure. Although more empirical evidence is needed to establish a clear link between earthquakes and anthrax reactivation, the convergence of climate change, migration, and environmental disruption warrants a multi-hazard approach in disease preparedness and policy planning.

Clinical and Research Consequences

Anthrax remains endemic in several regions of Türkiye, notably in the Northeast Anatolia (TRA), the Central East Anatolia (TRB), and parts of the Black Sea Region (TR8, TR9).[16,30]

Although national surveillance and vaccination programs[23] have contributed to a gradual decline in reported cases, their effectiveness remains uneven due to socioeconomic disparities, limited public awareness, and region-specific challenges such as climate vulnerability and inadequate infrastructure.

From a clinical perspective, cutaneous anthrax continues to be the most frequently diagnosed form in Türkiye, particularly in rural, livestock-dependent areas.[16,30] However, climate-induced changes in spore dynamics (e.g., aerosolization) may increase the risk of more severe forms such as inhalational anthrax, which has higher mortality and requires a rapid and specialized clinical management. In addition, increased environmental exposure through flooding, soil disruption, or improper carcass disposal can also complicate differential diagnosis in endemic settings.

From a research perspective, the prolonged environmental persistence of the *B. anthracis* spores poses a significant challenge for sustainable land use, particularly in the absence of effective remediation strategies. Current regulations in Türkiye focus only on the disinfection of contaminated facilities,[23] and carcass disposal methods such as burial with quicklime, whose effectiveness remains questionable,[37] generally leave contaminated pastures untreated. The lack of environmentally sustainable decontamination techniques, coupled with the risk of reactivation of dormant spores due to climate change, highlights the urgent need to identify and map undocumented "hidden hotspots." Addressing this research gap will require integrating local ecological knowledge, especially from farming communities, with geospatial and molecular tools to enhance hotspot prediction and inform the development of environmentally friendly remediation methods, which preserve both soil usability and ecological balance.[38,39]

Moreover, global evidence reinforces anthrax as a climate-sensitive zoonosis. Outbreaks in Sub-Saharan Africa, Central Asia, and Siberia have been linked to extreme weather events that disturb contaminated soils and facilitate spore reactivation.[19] Climate-based modeling studies from Kenya, Zimbabwe, and Bangladesh further suggest that anthrax risk zones may expand or shift due to changes in temperature, precipitation, and land use.[40,41] These findings underscore the importance of integrating climate projections into Türkiye's national risk mapping and developing interdisciplinary, climate-informed surveillance and mitigation strategies.

Conclusion

Anthrax continues to pose a significant public health and veterinary threat in Türkiye, particularly in endemic regions such as Eastern Anatolia. While current control efforts have reduced incidence, climate change introduces new ecological pressures that may alter the distribution, frequency, and severity of future outbreaks. A multidisciplinary and proactive approach is therefore essential to prevent the re-emergence or expansion of anthrax in both endemic and previously unaffected areas.

To enhance national preparedness and resilience, the following policy and practice priorities are thus proposed: (i) national risk maps should be updated by integrating regional climate projections, ecological vulnerability, and historical epidemiological data, (ii) vaccination and surveillance programs must be sustained and expanded to encompass areas identified as at risk under future climate scenarios, (iii) environmentally friendly decontamination strategies and biosecure carcass disposal methods should be developed, standardized, and widely implemented, (iv) cross-sectoral coordination between health, veterinary, environmental, and agricultural authorities should be reinforced within the One Health framework, (v) public education and community engagement should be prioritized to ensure local compliance and timely reporting, particularly in rural or climatically sensitive areas, (vi) research funding and capacity building should be supported for innovation in climate–pathogen dynamics, spore ecology, and sustainable remediation techniques.

Ethics Committee Approval: Ethical approval was not required for this study since this is a review article.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

Use of AI for Writing Assistance: Non declared.

Authorship Contributions: Concept: FB, MD; Design: FB, CC, YE, MD; Supervision: OC, MS, LB; Resource: FB, CC, YE; Materials: FB, CC; Data Collection or Processing: FB, YE; Analysis or Interpretation: FB, CC, OC, MD, MS; Literature Search: FB, CC, YE; Writing: FB, CC, MD; Critical Reviews: CC, OC, MS, LB.

Peer-review: Double blind peer-reviewed.

References

1. European Environment Agency (EEA). Climate change as a threat to health and well-being in Europe-Focus on heat and infectious diseases, Publications Office of the European Union, 2022. Available at: https://data.europa.eu/doi/10.2800/67519
2. Crippa M, Guizzardi D, Pagani F, Banja M, Muntean M, Schaaf E, et al. GHG emissions of all world countries. Luxembourg: Publications Office of the European Union; 2023.
3. Republic of Turkey Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology. Average Temperature in Turkey. 2024a. Available at: https://www.mgm.gov.tr/FILES/resmi-istatistikler/parametreAnalizi/2024-ortalama-sicaklik.pdf

4. Republic of Turkey Ministry of Environment, Urbanization, and Climate Change General Directorate of Meteorology. Rainfall in Turk. 2024b. Available at: https://www.mgm.gov.tr/FILES/resmi-istatistikler/parametreAnalizi/2024-yagis.pdf
5. Tokuşlu A. Assessing the impact of climate change on Turkish Basins. IJEGEO 2022;9(4):102-12. [CrossRef]
6. Chomel BB. Zoonoses. Encyclopedia of microbiology. 2009:820-9. [CrossRef]
7. Mohammadpour R, Champour M, Tuteja F, Mostafavi E. Zoonotic implications of camel diseases in Iran. Vet Med Sci 2020;6(3):359-81. [CrossRef]
8. Lee K. The Global Governance of Emerging Zoonotic Diseases. Published online February 13, 2023. Available at: Council on Foreign Relations.
9. Ergüner Y, Kumar J, Hoffman FM, Dalfes HN, Hargrove WW. Mapping ecoregions under climate change: A case study from the biological 'crossroads' of three continents, Turkey. Landsc Ecol 2019;34:35-50. [CrossRef]
10. Margistar. Connecting Europe and Asia since 480 B.C.: MARGISTAR Explores the Republic of Türkiye. Available at: https://margistar.eu/margistar-explores-the-republic-of-turkiye/
11. İnci A, Doğanay M, Özdarendeli A. Overview of zoonotic diseases in Turkey: The one health concept and future threats. Turkiye Parazitol Derg 2018;42(1):39-80. [CrossRef]
12. World Health Organization & International Office of Epizootics (WHO/OIE). Anthrax in Humans and Animals. 4th edition. Geneva: World Health Organization; 2008. Available at: https://www.ncbi.nlm.nih.gov/books/NBK310486/
13. Arı HO, İşlek E, Bilir Uslu MK, Özatkan Y, Karakaş F, Yıldırım HH, et al. The monetary impact of zoonotic diseases on society: The Turkish Case. Ankara Univ Vet Fak Derg 2022;69(1):9-15. [CrossRef]
14. World Health Organization (WHO). Mapping the Risk and Distribution of Epidemics in the WHO African Region: A technical report. World Health Organization. Brazzaville, Republic of Congo; 2016. pp. 38-39.
15. World Animal Health Information System (WAHIS) dashboard. Anthrax-Türkiye (Rep. of). 2025. Available at: https://wahis.woah.org/#/dashboards/qd-dashboard
16. Topluoglu S, Aktas D, Celebi B, Kara F, Doganay M, Alp E. Human anthrax in Turkey: A ten years' experience (2009-2018). Trop Doct 2021;51(1):80-3. [CrossRef]
17. Ezhova E, Orlov D, Suhonen E, Kaverin D, Mahura A, Gennadinik V, et al. Climatic factors influencing the Anthrax outbreak of 2016 in Siberia, Russia. Ecohealth 2021;18(2):217-28. [CrossRef]
18. Rume FI, Karim MR, Ahsan CR, Yasmin M, Biswas PK. Risk factors for bovine anthrax in Bangladesh, 2010-2014: a case-control study. Epidemiol Infect 2020;148:e67. [CrossRef]
19. Walsh MG, de Smalen AW, Mor SM. Climatic influence on anthrax suitability in warming northern latitudes. Sci Rep 2018;8(1):9269. [CrossRef]
20. Pittiglio C, Shadomy S, El Idrissi A, Soumare B, Lubroth J, Makonnen Y. Seasonality and ecological suitability modelling for anthrax (*Bacillus anthracis*) in Western Africa. Animals (Basel) 2022;12(9):1146. [CrossRef]
21. Simonova EG, Kartavaya SA, Titkov AV, Loktionova MN, Raichich SR, Tolpin VA, et al. Anthrax in the territory of Yamal: Assessment of epizootiological and epidemiological risks. Problems of Particularly Dangerous Infect 2017;1:89-93. [CrossRef]
22. Çalışkan O, Çalışkan A. Polar frozen climate areas of Turkey: Are there any actual glaciers in Turkey? In: Proceedings of the International Geography Symposium on the 30th Anniversary of TUCAUM; 2018 Oct 3-6; Ankara, Türkiye. Ankara: TUCAUM; 2018.
23. Ministry of Food, Agriculture and Livestock. Regulation on Protection and Fight Against Anthrax Disease. Decision Number: 23/12/2011-28151. [in Turkish]. [CrossRef]
24. Sahin M, Laws TR, Dyson H, Celebi O, Doganay M, Buyuk F, et al. Soil sample analysis of *Bacillus anthracis* contaminated animal burial sites. Microorganisms 2024;12:1944. [CrossRef]
25. Maksimovic Z, Cornwell MS, Semren O, Rifatbegovic M. The apparent role of climate change in a recent anthrax outbreak in cattle. Rev Sci Tech 2017;36(3):959-63. [CrossRef]
26. Saile E, Koehler TM. *Bacillus anthracis* multiplication, persistence, and genetic exchange in the rhizosphere of grass plants. Appl Environ Microbiol 2006;72(5):3168-74. [CrossRef]
27. Cusmano A, Baillie L. Is climate change driving an increase in cases of anthrax? 2023. Available at: https://www.the-microbiologist.com/opinion/is-climate-change-driving-an-increase-in-cases-of-anthrax/2192.article
28. Loiko N, Islam MN. Plant-soil microbial interaction: Differential adaptations of beneficial vs. pathogenic bacterial and fungal communities to climate-induced drought. Agronomy 2024;14(9):1949. [CrossRef]
29. Baldwin VM. You can't *B. cereus* - A review of *Bacillus cereus* strains that cause anthrax-like disease. Front Microbiol 2020;11:1731. [CrossRef]
30. Kadanalı A, Topluoğlu S, Aktaş D, Şahin M, Akbulut A, Kılıç S, et al. Current situation report of Anthrax in Turkey. Turk Hij Den Biyol Derg 2020;77(EK-2):1-20.
31. Kenefic LJ, Pearson T, Okinaka RT, Schupp JM, Wagner DM, Hoffmaster AR, et al. Pre-Columbian origins for North American anthrax. PLoS One 2009;4(3):e4813. [CrossRef]
32. Ochai SO, Crafford JE, Hassim A, Byaruhanga C, Huang YH, Hartmann A, et al. Immunological evidence of variation in exposure and immune response to *Bacillus anthracis* in herbivores of Kruger and Etosha National Parks. Front Immunol 2022;13:814031. [CrossRef]
33. İnci A, Yıldırım A, Düzlü Ö. The current status of ticks in Turkey: A 100-year period review from 1916 to 2016. Turkiye Parazitol Derg 2016;40(3):152-7. [CrossRef]
34. Doganay M, Demiraslan H. Refugees of the Syrian Civil War: Impact on reemerging infections, health services, and biosecurity in Turkey. Health Secur 2016;14(4):220-5. [CrossRef]
35. Price EP, Seymour ML, Sarovich DS, Latham J, Wolken SR, Mason J, et al. Molecular epidemiologic investigation of an anthrax outbreak among heroin users, Europe. Emerg Infect Dis 2012;18(8):1307-13. [CrossRef]

36. Plateforme ESA. Diffusion de la fièvre aphteuse SAT-2 en Turquie (Correction le 17/04/2023). Available at: https://www.plateforme-esa.fr/fr/diffusion-de-la-fievre-aphteuse-sat-2-en-turquie-correction-le-17-04-2023 [in French]
37. Alam ME, Kamal MM, Rahman M, Kabir A, Islam MDS, Hassan J. Review of anthrax: A disease of farm animals. J Adv Vet Anim Res 2022;9(2):323-34. [CrossRef]
38. Wood JP, Adrion AC. Review of decontamination techniques for the inactivation of *Bacillus anthracis* and other spore-forming bacteria associated with building or outdoor materials. Environ Sci Technol 2019;53(8):4045-62. [CrossRef]
39. Celebi O, Buyuk F, Pottage T, Crook A, Hawkey S, Cooper C, Bennett A, Sahin M, Baillie L. The use of germinants to potentiate the sensitivity of *bacillus anthracis* spores to peracetic acid. Front Microbiol 2016;7:18. [CrossRef]
40. John L, Shekede MD, Gwitira I, Mazhindu AN, Pfukenyi DM, Chikerema S. Modelling climate change impacts on the spatial distribution of anthrax in Zimbabwe. BMC Public Health 2024;24:632. [CrossRef]
41. Otieno FT, Gachohi J, Gikuma-Njuru P, Kariuki P, Oyas H, Canfield SA, et al. Modeling the potential future distribution of Anthrax outbreaks under multiple climate change scenarios for Kenya. Int J Environ Res Public Health 2021;18(8):4176. [CrossRef]
42. Türkiye Cumhuriyeti Resmî Gazete. Council of Ministers Decision on the Definition of Statistical Regional Units Classification (NUTS). 2002 Sep 22;24884 (Decision No.: 2002/4720). Ankara: Prime Ministry of the Republic of Türkiye.