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Climate Change, Climate Variability and Brucellosis

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Abstract: In addition to natural climate variability observed over comparable time periods, climate change is attributed directly or indirectly to human activity, altering the composition of global atmosphere. This phenomenon continues to be a significant and global threat for the humankind, and its impact compromises many aspects of the society at different levels, including health. The impact of climate change on zoonotic diseases has been largely ignored, particularly brucellosis. We here review some direct and indirect evidences of the impact of climate change and climate variability on brucellosis.

Keywords: Animal, brucellosis, climate change, climate variability, ecoepidemiology, epidemiology, human, zoonoses.

INTRODUCTION

Climate change, the shift attributed directly or indirectly to human activity that alters the composition of global atmosphere, in addition to natural climate variability observed over comparable time periods, which continues to be a significant global threat for the humankind [1-4]. Its impact compromises many aspects of the society at different levels. As it has been previously stated, health is one of the relevant elements affected by this enormous problem that represents the climate change [5]. Despite the impact of climate change on infectious diseases have been highlighted [6-16], its impact on zoonotic diseases has been largely ignored [17-23]. Many zoonoses are very prone to increase due to shifts in the distribution and behavior of vectors and animal species, which indicates that biologic systems are already adapting to ecological variations [17-23].

Zoonotic infections are in general defined as infections transmitted from animal to man (and less frequently vice versa), either directly (through contact or contact with animal products) or indirectly (through an intermediate vector as an arthropod or an insect) [24]. Although the burden of zoonotic infections worldwide is considered high; both in terms of immediate and long-term morbidity and mortality, [25, 26] and in terms of emergence/reemergence and socioeconomical, ecological, and political correlations [17]. The scientific and public health interest and the funding opportunities for these diseases have not received the corresponding attention [27].

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It is well established that climate is an important determinant of the distribution of different vectors and pathogens [2, 5, 15, 16, 18]. This has been extensively described for some tropical non-zoonotic diseases, such as those of malaria and dengue [5, 16, 28-32]. Although not yet accepted, recent evidences indicate that malaria would be also a zoonotic disease [33]. In the case of zoonotic diseases, leishmaniasis (vectorized by sandflies *Phlebotomus* spp. [in the Old World] and *Lutzomyia* spp. [in the New World] and caused by *Leishmania* spp.), should be probably the most studied of them, regarding the impact of climate change and variability in many parts of the World. Available evidences of these associations, at different levels, came from different countries in Latin America [5, 20, 22, 34-37], Africa [38, 39], Asia [40-42] and Europe [13, 43-48]. However, other zoonoses, such as brucellosis, which remains as the commonest zoonotic disease worldwide [49-52], have been largely neglected regarding studies assessing the impact of climate change variability on its epidemiology [53-55]. With a high burden in many countries, brucellosis accounts for more than 500,000 new cases annually [49-52], is associated with substantial residual disability [51, 56], and is an important cause of travel-associated morbidity [56-58]. The incorporation of new tools and disciplines, recently developed; such as ecoepidemiology [59-62], landscape epidemiology [63, 64], medical ecology [17, 65-68], geographical information systems [69-72] and remote sensing and satellite epidemiology [73-75], among others, could provide new insights on the potential influences of climate change and climate variability on infectious, tropical and zoonotic diseases, particularly those emerging and reemerging [76].

In this article, we review some direct and indirect evidences of the impact of climate change and climate variability on brucellosis.

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CLIMATE CHANGE AND ZOONOTIC DISEASES

The climate is an important determinant of the distribution of vectors and pathogens, such as those of malaria and dengue. However, more information is required for zoonoses that are important in different regions in the World, such as leishmaniasis, Chagas disease, toxocariasis, brucellosis [18-20, 22, 27, 56, 77]. Recent contributions in the field have demonstrated strong associations between climate variability, climate change and emerging and reemerging infectious diseases that represent public health issues for many areas in the World. These diseases and other zoonotic diseases represent a significant burden of disease, from highly endemic areas to those from lower endemic areas [18-20, 22, 27, 56]. These diverse epidemiological scenarios have suffered the impacts of climate change in the socioeconomical systems, such as agriculture and fishering, as a consequence of the phases of the El Niño Southern Oscillation (ENSO) phenomena, but also in specific health conditions such as infectious, tropical and zoonotic diseases; such as leishmaniasis, Chagas disease, toxocariasis, brucellosis, among others [18-20, 22, 27, 56]. Different statistical analysis, most of them based on linear regressions, have associated extreme climatic anomalies with significant alterations in the epidemiological patterns of diseases, sometimes coupled directly and indirectly on time and space. Additionally to statistic techniques, geographical information systems (GIS) and remote sensing (spatial epidemiology) have supported these observations and are helping in the development of systems for prediction and forecasting of such diseases based on climate variability and climate change, as it has been previously reported [36, 43, 78, 79]. Given the substantial burden of disease associated to climate change in developing tropical countries, it is of utmost relevance to incorporate climate changes studies into public health thinking and prevention. Then, the list of zoonotic diseases currently studied, regarding the impact of climate change and variability, that includes at least: anthrax [80], babesiosis [81], cholera [82], giardiasis [83], hantavirus infections [84], leishmaniasis [20, 22], leptospirosis [85], rabies [86], schistosomiasis [19, 21], yellow fever [87], among others, would be possibly included in the near future [77].

Although many studies still may have some limitations; such as the lack of incorporation of other meteorological factors into the analysis, it has been suggested that such findings are relevant, from a public health perspective, to better understand the ecoepidemiology of different diseases [2, 5, 87]. However, further research is needed in many regions of the World to develop monitoring systems that will assist in predicting the impact of climate changes in the incidence of these diseases in endemic areas with various biological and social conditions [2, 5].

CLIMATE CHANGE AND BRUCELLOSIS

In first instance, it should be clarified that, in many countries, there is a considerable lack of information of human and animal brucellosis, due to the lack of availability of the diagnostic techniques and in the public data on, records and surveillance of the disease, particularly in some countries of South America and Africa [56, 88]. Research on this zoonosis is still neglected in many countries of these regions. For South America, a database search (Medline) shows that there are only 9 articles published on brucellosis from Colombia, from 1809 to 2012. Similarly, in Venezuela 8 results can be obtained for the same period [89, 90]. From Ecuador, jut 2 references can be retrieved, as well as 3 from Paraguay, 3 from Uruguay and 1 from Bolivia [91-99]. In Africa, countries such as Tanzania, have published 15 articles on brucellosis, Kenya 35, Bostwana 2, Congo 8 and Cameroon 6 [100-104]. On the other hand, burden of morbidity and complications from this zoonotic and foodborne disease can represent a significant problem in many endemic areas in the World [105, 106].

Secondly, from an ecological point of view, it is important to understand that brucellosis can be caused by different species of the genus *Brucella*, hosted by different animal reservoirs: *B. melitensis* (animal hosts: sheep, goats, camels) being the most common cause of human brucellosis; *B. abortus* (animal hosts: cattle, buffalo, elk, yaks, camels), the second most common cause of human infection. Human infections have also been included after cases reported, *B. suis*, *B. canis*, *B. ceti* and *B. inopinata* [107].

The ecology where *Bru cella* species, pathogenic or not for the human beings, occur is highly diverse. The role of wildlife animals as a reservoir for human disease has already been outlined in the case of the risk to hunters [108-111]. Wildlife species naturally infected with *Brucella* can also serve as a reservoir for animal disease. This is the case with disease transmission between wild boar and domestic pigs and, more interestingly, between elk and cattle. The latter possibility has resulted in major political debate in the United States of America (USA) in recent years, with elk trapping, testing and, if positive, killing in the Yellowstone National Park area (Wyoming, USA) to avoid transmission of *B. abortus* to domestic cattle during grazing [107]. A recent DNA genotyping study confirmed that the origin of brucellosis affecting domestic and wildlife species in the Greater Yellowstone area was indeed the elk [112].

In the Greater Yellowstone Ecosystem, Wyoming, USA Fig. (**1**), where the free-ranging elk (*Cervus elaphus*) is a maintenance host for *Brucella abortus* [113], a study assessed how the increase on the transmission of brucellosis in those animals, may be affected by climatic factors, such as snowpack [55]. Those possibilities using snowpack and feeding data, from 1952 to 2006, and disease testing data, from 1993 to 2006, were assessed. Brucellosis seroprevalence was strongly correlated with the timing of the feeding season. Longer feeding seasons were associated with higher seroprevalence. However, elk population size and density had only minor effects. In other words, the duration of host aggregation and its association with peak transmission periods was more important than just the host population size. Accurate modeling of disease transmission depends upon incorporating information on how host contact rates fluctuate over time relative to peak transmission periods. They also found that supplemental feeding seasons lasted longer during years with deeper snowpack. Therefore, milder winters and/or management strategies that reduce the length of the feeding season may reduce the seroprevalence of brucellosis in the elk populations of the southern Greater Yellowstone Ecosystem [55].

Fig. (1). Map of North America showing places where some studies regard the impact of climate change and climate variability on animal brucellosis have been held (Wyoming and Alaska, USA).

Recently, the area-to-area variation of brucellosis in some endemic areas may be linked to ecological factors and differences in management practices [114]. Another consideration that should be taken into account is the potential influence of ecological factors; particularly climate change, the so-called ecotones, which are areas of transition in multiple conditions highly susceptible to be impacted by those changes [115, 116]. Brucellosis is one of the diseases that have been considered to affect, in terms of transmission, by the landscape modifications resulting from climate change, although further data are necessary to support this assumption [117]. Land changes can modify microclimates for livestock production, leading to habitat loss, increase the movement of domestic species and provide more chances for livestock to be in contact with wild species. These factors raise the exposure to *Brucella* and other new pathogens and the bidirectional transmission of emerging diseases (in livestock or wildlife). Wildlife trade intensified in areas affected by emergent diseases and cross-border illegal traffic will increase the risk of emergent disease transmission between wildlife and people [117], even in non endemic countries or areas [118-121].

In a recent study from northern Alaska, USA Fig. (**1**), the presence of specific antibodies to *Brucella* spp. in polar bears (*Ursus maritimus*) from southern Beaufort Sea during 2003-2006 was reported [122]. One possible explanation suggested for the annual variability, ranging from 7% to 19% in the period, is climate change [122].

In general, besides these studies, that were not specifically designed to address the impact of climate change on brucellosis, no other reports in the medical literature (indexed at Medline, Science Citation Index, Scopus and SciELO) can be found related to these specific interactions between that phenomena and this bacterial zoonosis.

Beginning with the consideration of the immediate environmental influences that can affect *Brucella* spp., since very long time it has been stated that this bacteria is capable of surviving for prolonged periods in the environment, and so inhalation of contaminated dusts in hot, dry countries (particularly in the tropics) may be a source of infection [123]. Microbiological studies have indicated that strains of *Brucella* grow optimally at 37ºC [123-127]. Therefore, this information would be consistent with the fact that climatic anomalies, altering the temperature and the humidity in the

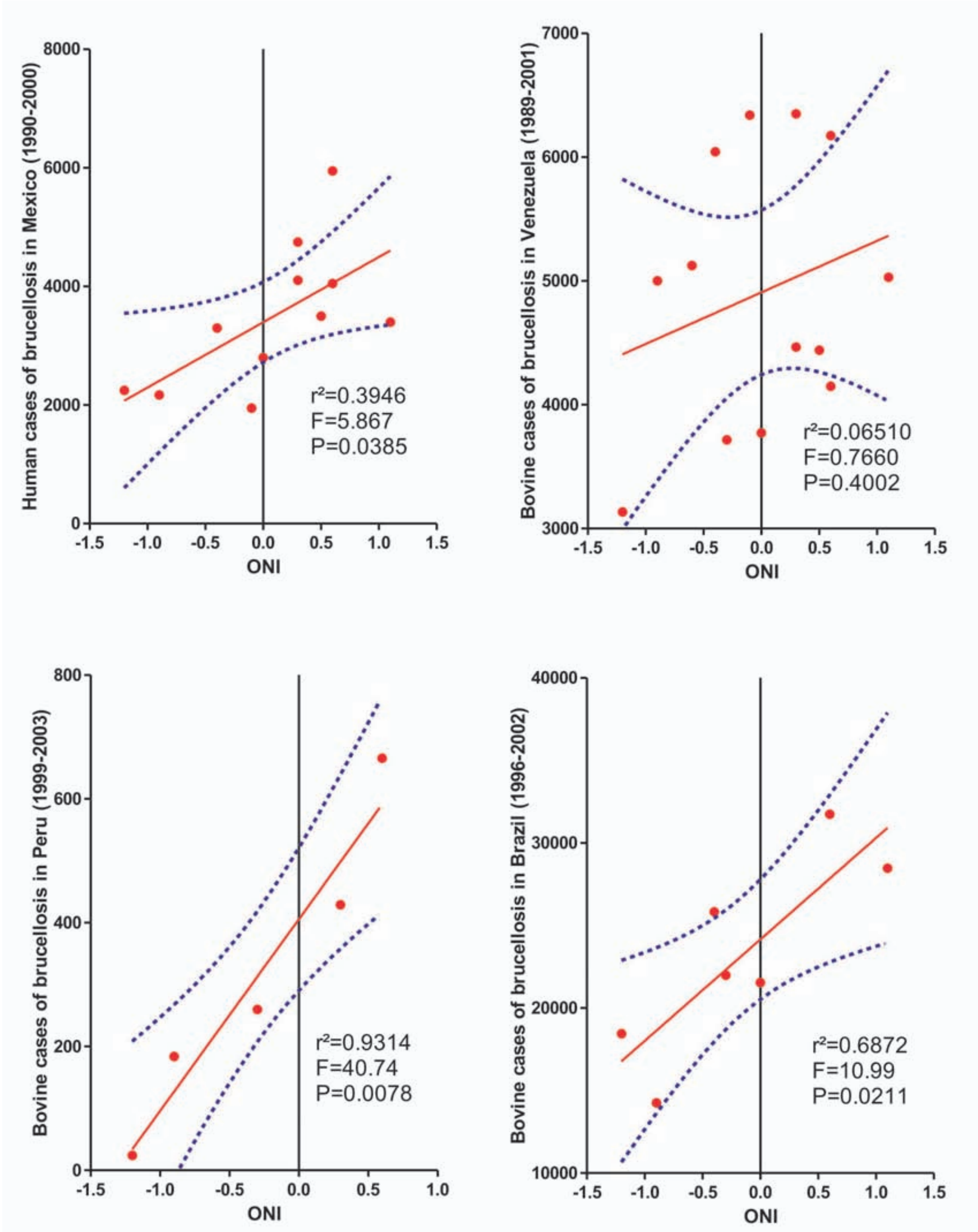

Fig. (2). Linear regression models between the Oceanic Niño Index (ONI) and the occurrence of cases of brucellosis in four Latin American endemic countries. Human cases in Mexico, 1990-2000 (left upper graph), bovine cases in Venezuela, 1989-2001 (right upper graph), bovine cases in Peru, 1999-2003 (left lower graph) and bovine cases of brucellosis in Brazil, 1996-2002 (right lower graph).

endemic environments, would affect the conditions for the persistence of *Brucella,* in its live and non-live reservoirs and hosts and, eventually, they would alter the capacity of Brucella to be transmitted to animals and humans.

Reviewing the epidemiology of brucellosis in some countries, it can be found that, for example in Mexico, this zoonosis remains as one of the most important reservoirs of human brucellosis. Data from the Mexican Ministry of Health's epidemiology directorate from the years 1990 to 2000 [128] were analyzed herein, in a linear regression model, using one of the macroclimatic indicators of climate change and variability. The Oceanic Niño Index (ONI) from the National Oceanographic and Atmospheric Agency (NOAA) showed that the higher number of cases that occurred during El Niño years (warm seasons), were significantly associated with the ONI Fig. (**2**). Conversely, using data from the Venezuelan Ministry of Health's epidemiology directorate from the years 1989 to 2001 [89], no significant relationship was found between the ONI and the occurrence of bovine cases of brucellosis in the country Fig. (**2**). However, in a shorter series of data for bovine brucellosis from the Ministry of Health of Peru [129], the same pattern observed for human cases in Mexico was observed, with the higher number of cases, that occurred during El Niño years (warm seasons), was significantly associated with the ONI Fig. (**2**).

In Brazil, where 162,314 cases of bovine brucellosis were reported between 1996 and 2002, according to the World Organization for Animal Health [130], the same pattern described for human cases in Mexico and bovine cases in Peru was observed. The higher number of Brucellosis that occurred during El Niño years (warm seasons), were significantly associated with the ONI Fig. (**2**).

In Venezuela, the human cases of brucellosis reported between 1996 and 1998, could be probably associated to the climate change shift and to an increase in the global temperature anomaly, as it could be observed by annual satellite images obtained from the Tropical Rainfall Measuring Mission (1 month - TRMM) imagery database of National Aeronautics and Space Administration [NASA] Earth Observations (NEO, NASA, USA) (http://neo.sci.gsfc.nasa.gov/) and analyzed for Venezuela with the software Google Earth® Fig. (**3**). Despite all these findings, more data series are necessary to confirm these quantitative and qualitative observations.

Considering the epidemiological and ecological information and the findings from those studies and such analyses, an explicative model on the potential influences of climate change on brucellosis can be preliminary developed Fig. (**3**). This approach has been taken for other climate-sensitive infectious diseases, particularly vector-borne and zoonotic.

CURRENT & FUTURE DEVELOPMENTS

Climate change produces threats to human health, safety, and survival via weather extremes and climatic impacts on food yields, fresh water, infectious diseases, conflict, and displacement [131]. Public health now has to consider many of these impacts in their perspectives for prevention, control and surveillance in all countries of the World [132, 133]. In the case of infectious diseases, many of them, including some zoonoses, have been recognized as potentially affected by climate change and climate variability [77]. However, the research of many zoonoses are still neglected in many aspects, including impact of climate change on their epidemiological patterns. This happens with brucellosis.

The research of Brucellosis is still neglected in many areas of the World, particularly in Latin America and Asia. In the case of impacts of climate change and climate variability, this situation is even more critical. Although some evidences have indicated that this zoonosis can be significantly affected by these factors, only few data are currently available to understand and support such associations.

Therefore, more research on the relationship between epidemiological variables, from humans and animals, as well as ecological, environmental and climatic factors is needed and justified for brucellosis.

The use of data available from several sources; such as the World Organization for Animal Health, records of human and animal brucellosis at country-level, from 1996 to

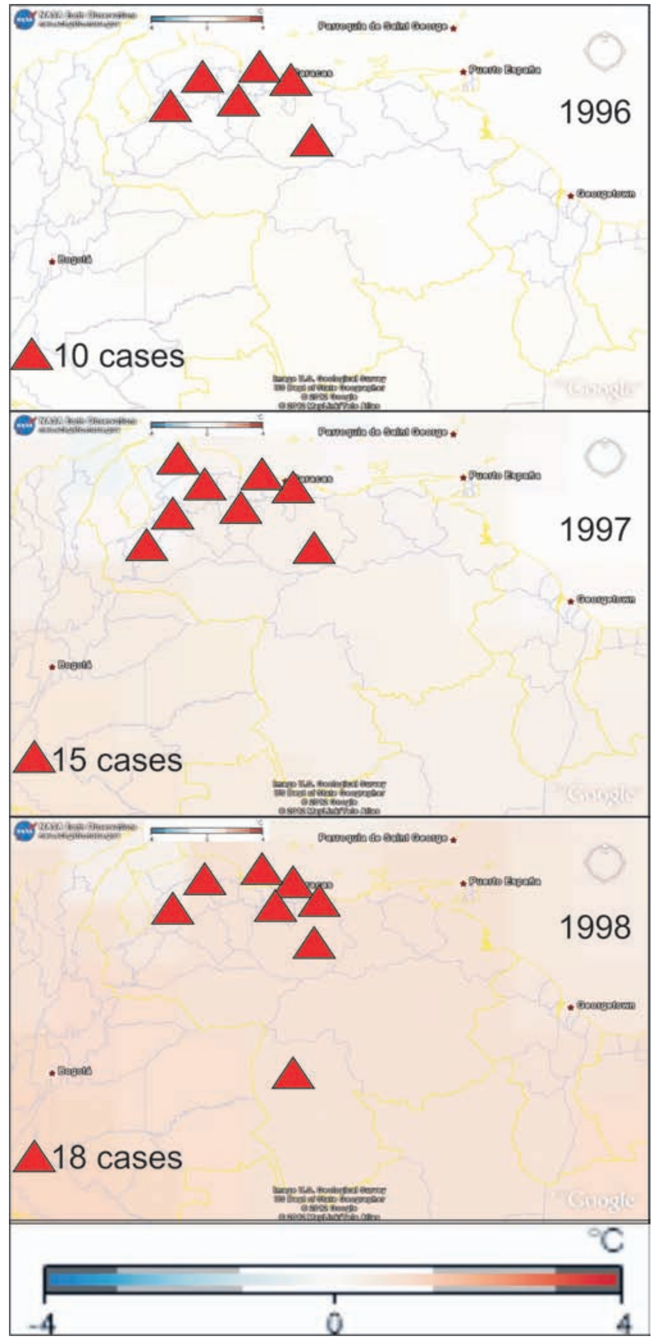

Fig. (3). Global temperature anomaly patterns maps from the TRMM satellite for Venezuela during 1996 to 1998 (NEO/NASA) and its potential relationship with human brucellosis report.

2004, as well as those from ministries and secretaries of health at country and states, departments of provinces, as epidemiological source with multiple climatic data, and variables currently available, such as those provided globally from NOAA and NASA, as well from environmental or meteorological national agencies, can provide insights into the impact of climate change on brucellosis, allowing the development of models and, ultimately, leading to climate-based forecast of disease, like early warning systems, developed

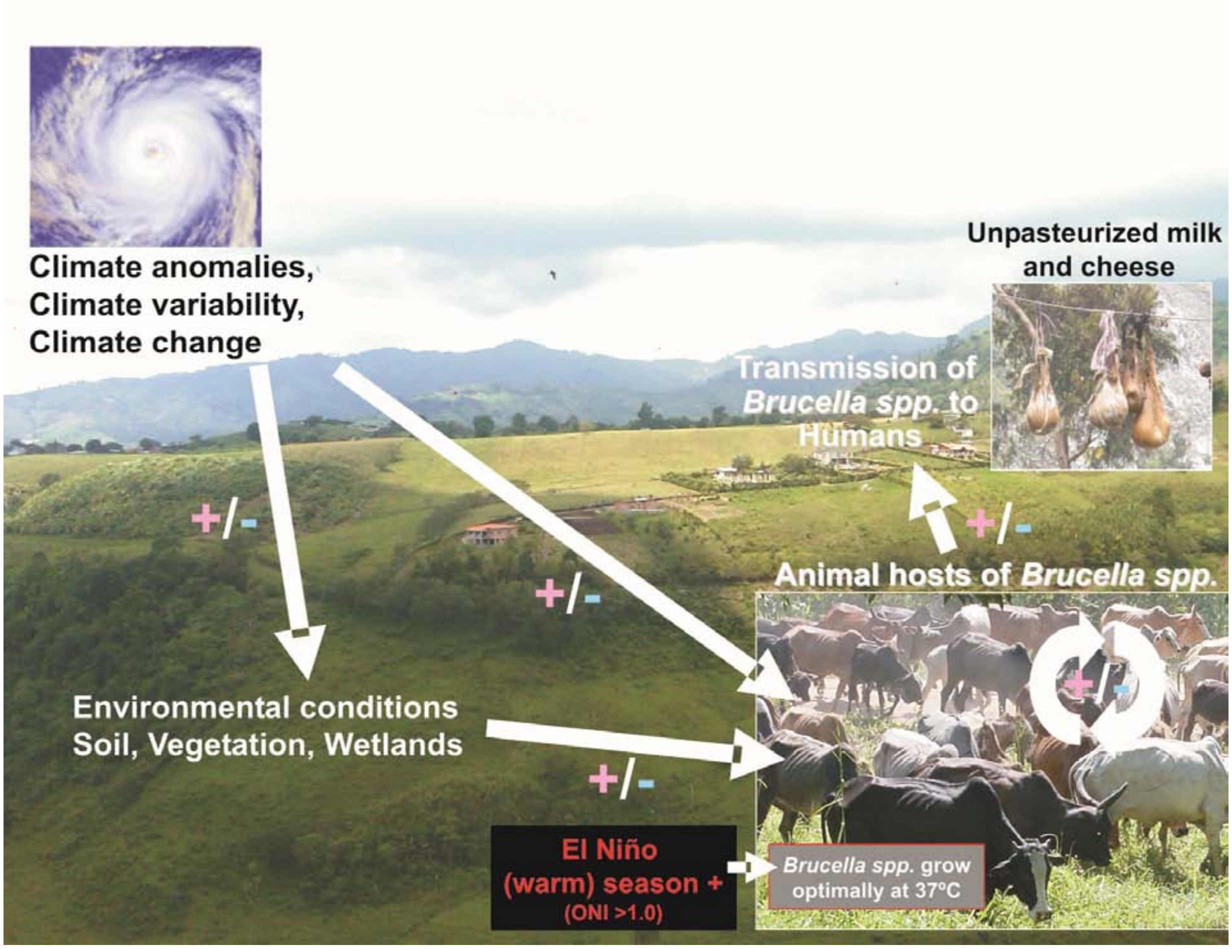

Fig. (4). Potential influences and impacts of climate change and climate variability on brucellosis.

for malaria, and other zoonosis and tropical diseases [73, 134-138], Therefore preventing the significant increase of the disease and improving the disease surveillance.

CONFLICT OF INTEREST

The author confirm that this article content has no conflicts of interest.

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