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Geographic Information System (GIS) and spatial distribution of bovine brucellosis in Egypt: A road Application Model.

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ABSTRACT

Bovine brucellosis is considered as a major neglected zoonotic disease that are still present in animal populations of several developing countries, such as Egypt. These countries generally have less effective control programs and present high-density livestock, illuminating competition for limited resources between the implementation of control strategies and the economic consequences of those strategies. It is well known that bovine brucellosis can potentially cause public health problems and animal welfare issues. The present study is designed to investigate the use of GIS in determining the spatial distribution of bovine brucellosis in Menoufia governorate. The current study attempts to investigate the GIS and spatial distribution as an efficient in disease mapping worldwide. This review spot highlights on this important view about these approaches and its application on bovine brucellosis as a model example in Menoufia governorate.

Keywords: Brucellosis, GIS and Spatial Distribution, Egypt.

1. INTRODUCTION

Many Egyptian farmers have relatively low socioeconomic conditions. Serious morbidities of farms, such as brucellosis, have adverse financial consequences (Khalafallah & Zaki, 2020). Similarly, abattoir institutions and veterinarians carry costs (Borham et al., 2022; Nossair et al., 2021; Youssef & Ahmed, 2014) . Therefore, this situation is associated with public health, financial, and agricultural consequences (Aden & Tukue, 2021; Elmonir & Ramadan, 2016; Holzer et al., 2021). The use of spatial mapping can help to manage brucellosis by assessing its spatial distribution and optimizing epidemiological surveillance measures, particularly in countries where detailed data are missing. Contiguous areas with a high risk of brucellosis transmission among animals can be defined by different clustering technologies. More attention can then be dedicated to these areas and their neighborhoods where the possibility of finding animal disease is greatest (Borba et al., 2013).

1.1. Background of Bovine Brucellosis

Bovine brucellosis is a major zoonotic disease with worldwide distribution. Brucella species are bacteria with a unique characteristic of being resistant to most disinfectants and can survive in the environment for a long time (Abd El-Wahab et al., 2019; Amin, 2019; Bagheri Nejad et al., 2020; Boschiroli et al., 2001; Cutler et al., 2005; Nerlich & Lösch, 2009; Pereira et al., 2020). Brucellosis is a chronic infection with slow progression at either the necropsy or the molecular levels in animals and are slow and difficult to treat in humans (Boschiroli et al., 2001; Kasir et al., 2023). The transmission dynamics of this disease is also slow; they occur through direct contact with infected animals, ingestion of contaminated feed or water, or inhalation (Churchyard et al., 2017; Pereira et al., 2020). Several countries worldwide started brucellosis eradication programs in the 1920s (Naugle et al., 2014; Neto et al., 2016; Zhang et al., 2018).

Bovine brucellosis is an ancient, economically important zoonotic disease. This disease affects large wild and domestic ruminant species. Infections could occur accidentally through sharing pastures, water sources, tools, or waste with infected domestic cattle. Control measures have been attempted and suspended, alarming international and national financial agencies. Zoonotic brucellosis continue to have economic and public health impacts in Egypt (Hegazy et al., 2011; Nossair et al., 2021; Nour & Nour, 2024). The most effective measures adopted by countries to control animal brucellosis include mass vaccination (Zhang et al., 2018). As a consequence, public health problems are associated with zoonotic brucellosis in developing countries (Naugle et al., 2014; Neto et al., 2016; Zhang et al., 2018).

2. Epidemiology of Bovine Brucellosis

Bovine brucellosis caused by *Brucella abortus* is neglected zoonotic disease of cattle with a global geographic distribution that also affects humans (Seleem et al., 2010; Une & Mori, 2007). Studying the epidemiology of these this disease is important to help identify their current prevalence and transmission dynamics over time. Furthermore, understanding the spatial epidemiology of this disease is important to understand the characteristics of their burden and to support resource allocation (El-Ghitany et al., 2014; Garcia-Saenz, 2015; Holzer et al., 2021; Khalafallah & Zaki, 2020). Globally, brucellosis is prevalent in the Mediterranean, Southeast Asia, South America, and Eastern and Western Africa, with the highest prevalence in the Mediterranean (Khoshnood et al., 2022; Zhang et al., 2019).

Several factors contribute to the occurrence of infectious diseases on an individual, local, regional, national, or international scale. Some factors can be considered a series of intrinsic disease variables, such as the pathogenesis of the agent or factors that contribute to infectivity. Other factors can affect their occurrence; for example, sex, age, breed, physiological stage, production systems, geographical areas, and management systems affect the occurrence and spread of bovine brucellosis in cattle (Abd El-Wahab et al., 2019; Borba et al., 2013; Elmonir & Ramadan, 2016; Hamed et al., 2021). However, true prevalence rates of brucellosis is still challenging for most of the world, particularly in some African, Middle Eastern, and Latin American countries. Countries like Egypt, which is considered a high disease burden area, face many challenges in conducting valid epidemiological studies due to available resources in general and veterinarians in particular (Abd El-Wahab et al., 2019; Elmonir & Ramadan, 2016; Hamed et al., 2021).

A major outcome of chronic diseases is their negative economic impact on global agriculture and trade. This loss mainly occurs in developing countries that rely on livestock production as an essential means of living. Current trade and politics are significant restrictive factors to alleviate this burden (Aden & Tukue, 2021; Elmonir & Ramadan, 2016; Holzer et al., 2021). In general, there are several factors related to the epidemiology of these diseases, particularly environmental and social factors, such as low population density, ecological variation, varied farming systems, and management practices, that have adequately explained the observed prevalence distribution in Egypt thus far (Glaziou et al., 2013; Khalafallah & Zaki, 2020).

2.1. Methods applied for surveillances of bovine brucellosis in Egypt

Bovine brucellosis remain threats to animal health and public health in many countries around the world (Dean et al., 2012; Glaziou et al., 2013).

Methodologies used to assess the prevalence of bovine brucellosis included field studies, laboratory methods, and interviews. Infection rates, geographic distribution, potential risk factors, animal husbandry practices, behaviors, and farmers' knowledge, attitudes, and practices towards these diseases were determined. Tests used included bacteriological examinations for tissue samples and milk collected from diseases animals; an indirect ELISA using an in-house coated antigen. Samples from the slaughterhouse; the samples should be obtained from the main suppliers for the abattoir. Direct interviews should be conducted with farmers, abattoir workers, and veterinarians, respectively (Khoshnood et al., 2022; Pereira et al., 2020; Zou et al., 2018). For example, bovine brucellosis is present in Egypt, but little is known about their geographical distribution (Abd El-Wahab et al., 2019; Amin, 2019). Similar at-risk countries, especially those neighboring Egypt and the countries with the same locations showed a relatively high but variable prevalence (Boschiroli et al., 2001; Kasir et al., 2023). Infections like these drain resources and resilience against food security, and the efforts to complete treatment without any interruption are typified. Evidence shows that one way to effectively control such diseases is to address the related risks at national and regional levels. Consequently, the provision of effective disease prevention and treatment requires the use of epidemiological data to develop better control strategies (Neto et al., 2016). To localize any level of brucellosis prevalence, various studies can be used, for example: on cattle farms, on wildlife, in abattoirs at the level of meat inspection, or as a whole on the human population (Borba et al., 2013; De Garine-Wichatitsky et al., 2013; Dean et al., 2012; Elmonir & Ramadan, 2016; Hamed et al., 2021; Nasr et al., 2019). Specifically, control strategies should also be based on local and country-specific epidemiological data, as the distribution of these infections can vary considerably from one geographic area to another (Pereira et al., 2020; Zhang et al., 2018).

Several studies were conducted to investigate the distribution of bovine brucellosis in Egypt. The methodologies applied for these studies include serological surveys, epidemiological modeling, and molecular genotyping. They included both national and local surveys. In terms of study design, many types of samples from a variety of specimen sources have been investigated. The findings of these studies showed that the frequency of bovine brucellosis in cattle and buffalo varies widely among different regions in Egypt. Genotype-induced molecular techniques for differentiation of *B. abortus* showed the predominance of *B. abortus* biovar 1 in the isolates from different species (Abdellrazeq et al., 2016; El-Ghitany et al., 2014; Holzer et al., 2021; Khalafallah & Zaki, 2020; Nasr et al., 2021).Generally, the results of research conducted on bovine brucellosis in Egypt have a specific objective, which is to elucidate the epidemiological features of the disease in Egypt and to show the methods of prevention and control of these diseases (Abd El-Wahab et al., 2019; Holzer et al., 2021).

2.1. Impact on Livestock Industry

An extensive spatial analysis of one of the most prevalent cattle diseases in Egypt, namely bovine brucellosis, does not exist, and the available knowledge for these this disease is based on clinical, bacteriological, and/or serological and immunological work (Hegazy et al., 2011). Even upon reviewing the reported literature, there is no spatial distribution that defines their spread.

The role of bovine brucellosis in influencing the movement and trading of animals has changed over the years. Trade restrictions have led to considerable losses for countries where these diseases continue to be prevalent. The estimated potential losses due to reduced milk offtake caused by brucellosis were significant, with a human incidence rate of 10%. Abortion in brucellosis can cause a 10–45% loss of calf crops (Aden & Tukue, 2021; Elmonir & Ramadan, 2016; Holzer et al., 2021).

Besides, movement restrictions due to zonation and market access issues may reduce the selling price by up to 83%, increase veterinary costs at least seven-fold in terms of efficacy tests and vaccination costs, and may result in up to eight times the costs of testing and 18 times the cost of vaccination. If a single cow is diagnosed as positive, during the course of one year of quarantine, any loss of milk equates to a significant amount (Zinsstag et al., 2006). For brucellosis, the coverage of the disease among cattle and buffalo ranges from 21% to 38%, with the least number in certain regions (Boschiroli et al., 2001;

Kock et al., 2021; Seleem et al., 2010; Une & Mori, 2007).

3. GIS Applications in Disease Mapping

Over the past decade, Geographic Information Systems (GIS) have provided important tools for disease mapping and the visualization of spatial epidemiological data across various geographical levels, including internals, provinces, and farms. Using GIS tools, researchers could detect the spatial distributions, and any spatiotemporal patterns associated with bovine brucellosis in small and large ruminants. From a traditional point of view, pathological, bacteriological, immunological, and molecular studies offer the direct means of epidemic investigations. In order to expand these conventional approaches, researchers therefore have an incentive to integrate GIS technology to facilitate monitoring the spatial distribution of infections among farm animals (Durr & Gatrell, 2004).

The objectives of disease mapping and visualization of the spatial distribution consist of assessing the contribution of regional and environmental factors to disease spread and epidemiological investigations; matching potential risk areas in order to concentrate limited resources for effective governmental control strategies; and monitoring the spatial and temporal spread in the course of the repetitive programs for eradication or control (Mengistu & Haile, 2017). In addition, the results add another layer of data interpretation that could help to answer some epidemiological questions and raise new ones related to the transmission and identification of the source of infection. Epidemiological data, e.g., infection prevalence, incidence, seroprevalence, and case reports, can be linked to the spatial referring basis. In such a way, the relevant information can be represented graphically and analyzed with respect to maps, graphs, forms, and charts as a part of translations for a broad audience, either by professionals or young veterinary and medical students. The potential of GIS technology has evolved and influenced decision-makers to enhance environmental surveillance and control measures for the benefit of public health (Arıkan, 2009; Mengistu & Haile, 2017; Norstrøm, 2001).

3.1. Overview of GIS Technology

GIS is an integrated system composed of hardware, software, and data to capture, manage, analyze, and visualize spatial relationships for complex problems. Geospatial information can provide valuable decision-making data through accurate spatial visualization and geographic data analysis. Socioeconomic status, transportation hubs, human activities, livestock husbandry, and environmental changes significantly influence the regulation of livestock disease distribution and transmission (Norstrøm, 2001). For a substantial contribution to animal disease management, disease spatio-temporal distribution, efficient intervention sites, and feasible policies must be evident. Animal disease data are therefore vital as pivotal decision support. Precise disease data can provide valuable viewpoints for animal disease control purposes. This is especially true for the effective design of policies and plans for disease interventions. The use of geospatial technology has a strong influence on different public health interventions with special concern, such as vaccination, strategic sampling, and risk evaluation in animals. The public health intervention against brucellosis in animals is an important for eradication strategies. Geographic information systems can be used to explore numerous fields of public health interventions, such as spatio-temporal disease distribution, generating heavy risk area maps, analyzing correlations, and conducting simple or advanced spatial queries and model functions (Mengistu & Haile, 2017). With the globalization of research and internet technologies, there is currently relatively good scientific knowledge on GIS methodologies in the form of user-friendly package applications. Stakeholders such as veterinarians, policymakers, and public health authorities are able to utilize the package GIS applications for public health concerns without previous scientific knowledge and complicated geographical elaborations. In recent years, considerable levels of strain have been expended in the world use of user-friendly epidemiological GIS packages for both stakeholders. Study results indicate that GIS could facilitate the evaluation of public health animal disease policies (Arıkan, 2009; McKenzie, 2004).

3.2. Benefits of GIS in Disease Surveillance

GIS is useful to track disease spread through spatial analysis and visualization techniques and can be used to identify hotspots and prioritize geographic areas targeted for chemoprevention interventions. These actions can reduce the impact of the disease, especially in developing countries. Using bovine brucellosis as an example, the spatial distribution of this disease in Egypt was studied so that better surveillance could be established, and efforts could be directed towards endemic areas. GIS results can provide real-time data. This is valuable where resources are insufficient; rapid distributional response activities prioritize areas that are most affected (Durr & Gatrell, 2004). Therefore, GIS can show the most susceptible areas at a specific time. In this sense, different sectors are expected to work together: decision-makers and government institutions, research and educational institutions, zoo technicians, veterinarians, and farmers. Epidemiological data can be supplemented with socio-economic data, such as human population density, the type of commercial industry, and the presence of wildlife, to provide a better understanding of infection dynamics with the possibility of formulating test messages to guide disease prevention and control measures. Altogether, the use of GIS analysis in disease surveillance systems in both developed and developing countries is essential. The use of GIS in developing countries is essential because the role of communication among veterinary authorities, local and central authorities, and farmers is crucial. In this way, the combined use of different data types is essential for decision-making with 'as much information as possible' (Durr & Gatrell, 2004; Norstrøm, 2001).

3.3. Materials and Methods for GIS Applications in Disease Mapping

Data should be gathered from a variety of sources. Samples (including cattle serum, milk, and milk whey) should be collected from Native and Friesian cattle at home barns. Determination of brucellosis have to be conducted in laboratories. Infection rates should be determined by laboratory diagnosis (Mengistu & Haile, 2017).

Geographic information systems tools and image analysis can be used to map of brucellosis and execute the investigation. They can also be used for spatial analysis. All spatial reference information should be given in the spatial reference system. Data processing could be carried out in Excel prior to importing statistical data. Data from different databases should be determined by subjecting all brucellosis cases to an integrated statistical analysis. Descriptive research methods should be used to demonstrate the findings visually (Norstrøm, 2001).

Data protection and respect for the privacy of geographical and personal data regarding the animals and geographic location of the infected host should be obtained. In both databases, a unique code has to be used for each animal. Excel databases should be set up: database that gave information about the brucella-infected cattle (Durr & Gatrell, 2004).

3.3.1. Data Collection and Sources (Decker, 2001)

The research on the prevalence of bovine brucellosis is based on typical data divided into two types: quantitative and qualitative. The quantitative part is essentially based on some laboratory and laboratory-related data: the results of the Region and Governorate Veterinary Directorates' activities aiming to control the diseases, the results of the animals' export regulations and treatments, and the records of the private farm veterinarians who are responsible for testing private animal farms. The qualitative part is based on the experiences and perspectives of a wide range of actors that are relevant or involved somehow in the field of the study, like veterinary staff, lab staff, and farmers.

The field surveys methodology is largely based on guidelines for socio-economic and epidemiological field studies, which start with showing the objectives and the significance of the study to ensure field teams and stakeholders are aligned. The authorized staff of the RVD prepares a field team from veterinary services responsible for the controls. The survey covers all regions of the governorate, except for the desert land and the Red Sea and Mediterranean coastal strips. This is largely forced by the fact that the vast majority of animals (and farmers too) live on a strip that is almost confined to the Nile. Before the field visits, the heads of the animal and the owners' portfolios were determined, and at the office of the governor or through special statements of the borders, it was determined that the animals' herd or holder of the distributed inventory in every residential unit. Creating a cell map was one of the research requirements to ensure that there is no actual forward and backward research from all areas. The involvement of stakeholders, including farmers, veterinary medical teams, and laboratory workers as valuable sources of background information, is mandatory for any successful field study. Even if some stakeholders will participate in the subsequent field survey, their involvement during this step is critical and may help to set the priority topics. They are a treasure trove of information, and such shared information may be considered a main guide to uncover the causes of failures. That is why the indicators, the objectives, and questions are generated through the shared prioritization step by the team. Non-participant observation was performed by the team. Despite the challenges in communicating with stakeholders at the onset of the survey, it is worthwhile to reach out to multiple stakeholders. The main objectives of the field surveys and the rationale for using qualitative and participatory approaches are to validate the information obtained from other sources and to complete the available information to provide background to the study of the disease. Also, to establish the real situation of the epidemiology of the disease in the area of the study. To enable stakeholders to develop plans for future research, interventions, and livestock extension services through infection control.

3.3.2. GIS Data Processing Techniques (Nagy & Wagle, 1979)

Data analysis begins with preparing data, including data cleaning and mining, considering the current objective. The first step is to move some epidemiological and climatic layers to ArcGIS to integrate them in constructing maps. The analysis will lead to a good understanding of disease structure and variables that appear to have some apparent impact on distribution. Normalization was performed using the norm.inv.1 approach in ArcGIS. Shuffling of data to build normal capacity functions was repeated 999 times for significant value calculation, which was assumed in the 5th percentile, the upper 95% confidence interval for each generated normal capacity layer.

Several studies have used one of the two GIS software programs to spatially map disease occurrence and/or prevalence. GIS spatial statistical toolkits were used to standardize datasets, create hotspot analysis, and undertake a Mojena test using a spatial clustering module. The visual representation and statistical inference were produced using ArcGIS. Disease data was represented as points on basic maps using Quantum GIS and was managed using Access, Excel, and QGIS. Techniques of data visualization were conducted in terms of thematic maps that mapped the distribution of each variable used in univariate analysis and were checked in bivariate analysis for separate visualization of the distribution of cases.

Methods for data visualization in terms of thematic maps that mapped the distribution of each variable used in univariate analysis or checked on bivariate analysis were checked as separate visualization for the distribution of cases when the correlations or the relationships between each pair of variables were not significant, and then overlaying of significant relationships appeared in multivariate analysis. The application of the different tools for spatial and spatio-temporal analysis for disease presentation is the basic principle of building these analyses aimed to map and visualize the distribution of the target disease, whether it is infectious, parasitic, or any condition of interest. Moreover, these tools can create a new refined equation showing the relationship between the different variables, including environmental, socio-economic, and epidemiological variables that can expand the understanding of animal disease epidemiology.

4. Spatial Analysis of Bovine Brucellosis in Menoufia governorate

The spatial distribution of bovine brucellosis from most parts of Egypt can be divided into maps showed two hotspot areas for brucellosis.

The hotspots for the two infectious diseases that are mainly associated with the availability of livestock in the domestic hinterland. Careful interpretation of these results allows the Egyptian veterinary authorities to use this data for initiating the priority task of case identification, notification, and elimination of cross-infection. The data can be obtained from pre-existing surveys, and it is certainly not a replacement for well-structured clinical and serological testing, which may be conducted by well-trained biostatisticians or microbiologists. Rather, the information available would seem to be a satisfactory substitute, informative in its own way. The spatial analysis is easily applicable and that, accompanied by geographical information system tools, it can provide supplementary tools for disease control decision-making. The data should be monitored continually; recent, accurate results are vital.

4.1. Mapping Hotspots

The idea behind a hotspot is identifying high areas of diseases. Hotspots are frequently used with spatial data to screen surveillance data and find "disease pockets". One of the outputs that can be obtained from a hotspot mapping technique is that it uses spatial data to identify any area that has a high prevalence of a certain disease. Hotspots may be used to prioritize areas that need immediate intervention from the veterinary authority and allocation of resources rather than treating all areas with the same priority and resource allocation. Exploring hotspots from counties, governorates, or other administrative levels may be useful in formulating surveillance strategies and is also beneficial for pastoral and agro-pastoral communities in prioritizing resources and allocation. Hotspot maps might give stakeholders a good spatial picture of the disease distribution in a specific area at a specific period. In terms of food security, public health, and zoonotic disease control, areas with disease hotspots can help in the implementation of targeted control strategies.

4.2. Interpretation of Results

After conducting the spatial analysis, hotspot areas of bovine brucellosis in Egypt can be identified at the governorate level at a local spatial scale, where co-infections of this disease can be detected in certain governorates. Governorates with the largest number of susceptible and reactive herds identified in the area of one hotspot. The hotspots seem to be associated with the environmental and socio-economic factors in the geographical regions they protrude within. The identification of the prespecified hotspots is useful to guide control policies against these and other infectious diseases and global pollutants. The specific factors of high prevalent diseases may be different in space and time but mainly relate to environmental, climatic, and economic factors as well as interaction between such.

The understanding of such spatial dynamics and patterns, modeling and mapping of the prevalence, potential co-infections, and risk factors may help develop control strategies and in selecting the right target for specific and different sets of interventions. The following factors may facilitate the distribution of the diseases to the hotspot areas and their natural hosts depending on the presence of the risk factors as well: their movement, the densities of farms, veterinary services, and/or wild, stray, and domestic mammals in the area and the hygiene practices. Analysis of the various possible interactions between these variables in space and over time is paramount to policymakers in order to evaluate and manage risk. The establishment, management, and strengthening of the effective geographical information system and pedological workstation with the coordination of national and international institutions are also needed for regular, intensive monitoring of farms and wildlife with the emphasis on accurate collection of data and disease investigation. Further research activities for such processes may then include ecological aspects of animal populations and reliability of the data at display.

5- Model application of GIS and spatial distribution for bovine brucellosis in Menoufia governorate

5.1. METHODOLOGY

5.1.1. Data sources

Bovine brucellosis in Menoufia governorate were collected from General Organization for Veterinary Services **(GOVS)** during the period (2019-2021). *The prevalence rate was defined as "the confirmed presence of disease, clinically expressed or not, in at least one individual in a defined location and during a specified period".* The records included information such as location, species affected, index date, number of cases, number of outbreaks, and total population at risk.

5.1.2. Data analysis

Microsoft Excel spreadsheets (Microsoft Corporation) and R 4.2.3 (R Core Team) were used to manage the data and draw charts. Descriptive methods were used to calculate outbreak incidence. Prevalence is the number of cases of a disease that are present in a particular population at a given time (MedicineNet, 2023).

5.2. RESULTS

The data in table (1) and fig (1) reported the prevalence rate of brucellosis in both large and small ruminants among different localities in Menofuia governorate during 2019. It was clear that Ashmun, and Birkat Al-Sab recorded the higher prevalence rate among all examined ruminants (large and small). In accordance to prevalence of brucellosis in large ruminants, Ashmun, and Birkat Al-Sab recorded the higher prevalence, while Birkat Al-Sab, and Quwisna recorded the higher prevalence among small ruminants.

5.2.1. ***Prevalence of Brucellosis in different localities in Menoufia Governorate during 2019***

Table (1): Prevalence of Brucellosis in different localities in Menoufia Governorate during 2019

Locality	Large ruminants			Small ruminants			Total prevalence
	Cases	Total population	Prevalence	Cases	Total population	Prevalence	
Quwisna	0	151766	0	3	70525	0.004254	0.001
Shibin al-Kum	9	76179	0.011814	0	53252	0	0.007
Tala	6	93739	0.006401	11	58608	0.018769	0.011
Al-Shuhada	8	105165	0.007607	10	50925	0.019637	0.012
Minuf	36	115138	0.031267	13	51684	0.025153	0.029
Al-Bagur	21	62988	0.03334	11	37812	0.029091	0.032
Ashmun	81	102776	0.078812	11	65811	0.016715	0.055
Birkat Al-Sab	17	30474	0.055785	8	9233	0.086646	0.063

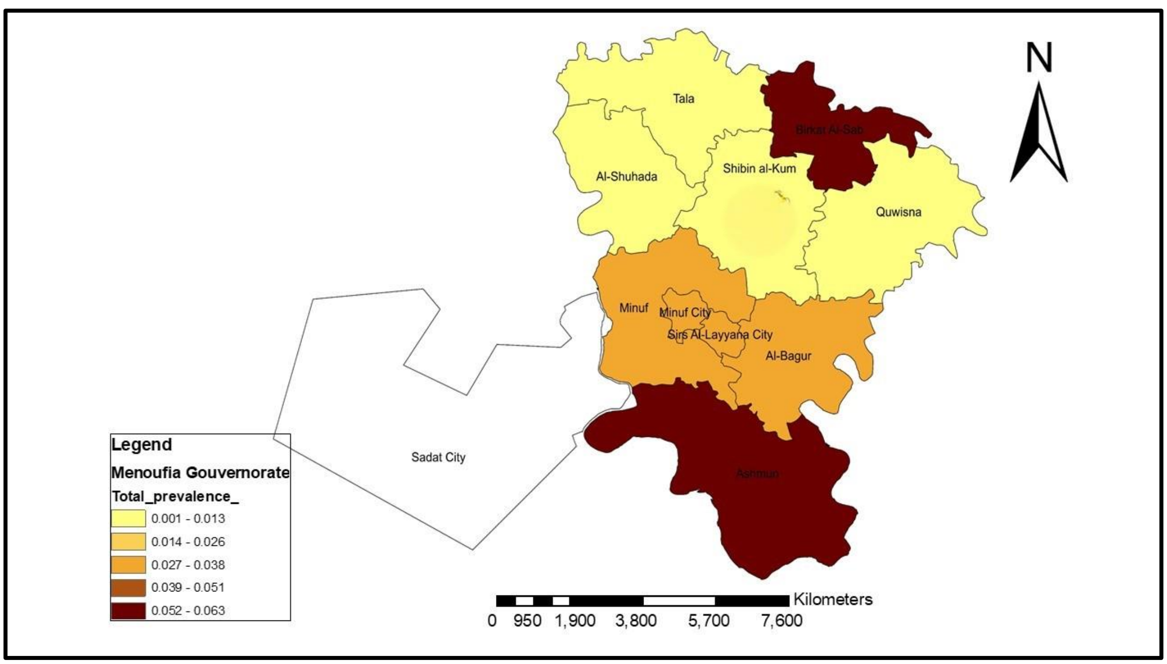

Figure 1: Geographical distribution of Brucellosis outbreaks in Menoufia Governorate during 2019

5.2.2. ***Prevalence of Brucellosis in different localities in Menoufia Governorate during 2020***

The data in table (2) and fig (2) reported the prevalence rate of brucellosis in both large and small ruminants among different localities in Menofuia governorate during 2020. It was clear that Tala and Minuf recorded the higher prevalence rate among all examined ruminants (large and small). In accordance to prevalence of brucellosis in large ruminants, Tala and Minuf recorded the higher prevalence, while Ashmun and Birkat Al-Sab recorded the higher prevalence among small ruminants.

Table (2): Prevalence of Brucellosis in different localities in Menoufia Governorate during 2020

Locality	Large ruminants			Small ruminants			Total prevalence
	Cases	Total population	Prevalence	Cases	Total population	Prevalence	
Birkat Al-Sab	1	25210	0.003967	2	4383	0.045631	0.01
Quwisna	6	40241	0.01491	3	2960	0.101351	0.021
Al-Shuhada	8	32545	0.024581	0	3889	0	0.022
Ashmun	23	67541	0.034053	6	8638	0.069461	0.038
Al-Bagur	6	32378	0.018531	12	5624	0.213371	0.047
Tala	15	35809	0.041889	6	3528	0.170068	0.053
Minuf	33	53352	0.061853	2	8429	0.023728	0.057

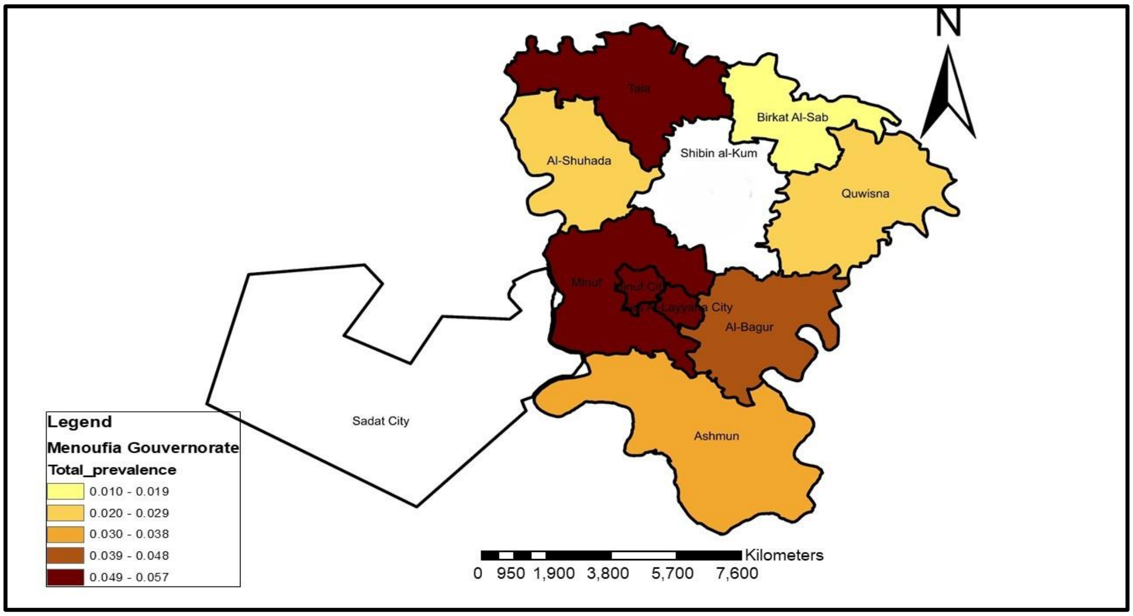

Figure 2: Geographical distribution of Brucellosis outbreaks in Menoufia Governorate during 2020

5.2.3. Prevalence of Brucellosis in different localities in Menoufia Governorate during 2021

The data in table (3) and fig (3) reported the prevalence rate of brucellosis in both large and small ruminants among different localities in Menofuia governorate during 2021. It was clear that Tala, Ashmun and Birkat Al-Sab recorded the higher prevalence rate among all examined ruminants (large and small). In accordance to prevalence of brucellosis in large ruminants, Ashmun, Al-Shuhada and Tala recorded the higher prevalence, while Al-Shuhada,Al-Bagur and Birkat Al-Sab recorded the higher prevalence among small ruminants.

Table (3): Prevalence of Brucellosis in different localities in Menoufia Governorate during 2021

Locality	Large ruminants			Small ruminants			Total prevalence
	Cases	Total population	Prevalence	Cases	Total population	Prevalence	
Al-Bagur	6	33009	0.018177	4	5721	0.069918	0.026
Birkat Al-Sab	2	18130	0.011031	12	2305	0.520607	0.069
Tala	19	34800	0.054598	8	3280	0.243902	0.071
Ashmun	39	63011	0.061894	12	6495	0.184758	0.073
Al-Shuhada	20	33111	0.060403	28	3886	0.720535	0.13
Minuf	76	36400	0.208791	4	3600	0.111111	0.2

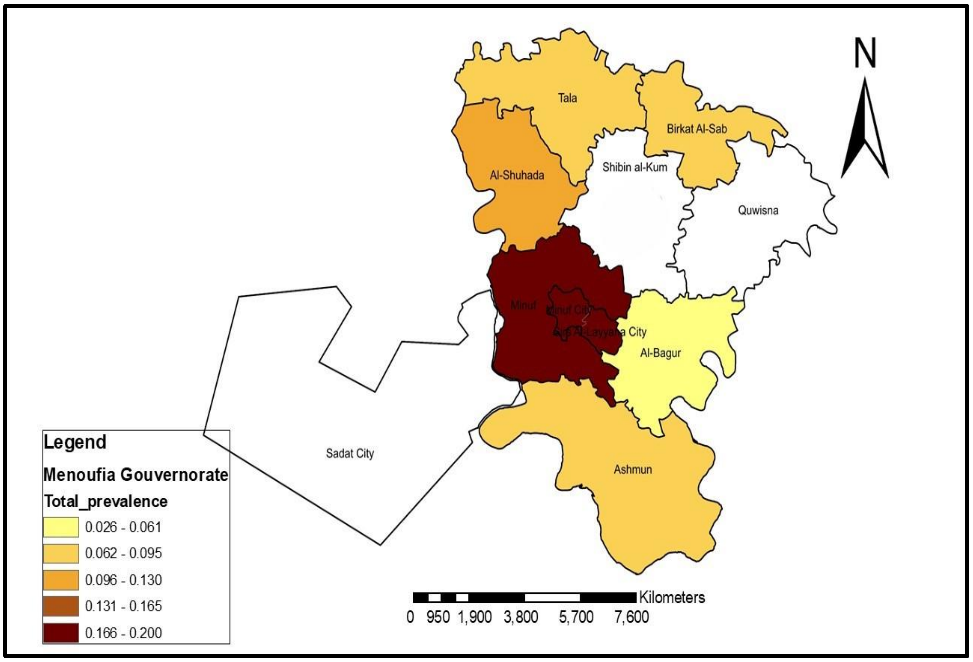

Figure 3: Geographical distribution of Brucellosis outbreaks in Menoufia Governorate during 2021

6. CONCLUSION AND FUTURE DIRECTIONS

The spatial distributions can give additional insights into the epidemiology of bovine brucellosis in Egypt. GIS technology application is useful in understanding the distribution of bovine brucellosis in this system, which will be helpful in initiating strategic control and surveillance studies. Because these animal diseases are also zoonoses, public health policies should be aware of these societies, as well as the impact of these diseases on general health. In addition, GIS spatial distributions of these diseases analyses may, however, be limited by the hatchery level of this spatial unit. Future work could consider this level for a finer scale distribution reflector, especially that honors the large geography and farm-level epidemiology of this system, and to achieve enough spatial units for robust spatial statistics. It is also important to handle the parasitism of social phenomena better than the application in integrating animal health, and the environment. Efforts should be made to conduct more serological tests from domestic animals and other wildlife, as suggested for the complete understanding of the epidemiology of bovine brucellosis. In this ecosystem, establishing a field test for the diagnosis of simultaneous infections with Brucella of the same species is also essential, as is collaborative work with stakeholders that promote full cooperation and the implementation of survey studies in Egypt.

6-REFERENCES:

Abd El-Wahab, E. W., Hegazy, Y. M., El-Tras, W. F., Mikheal, A., Kabapy, A. F., Abdelfatah, M., Bruce, M., & Eltholth, M. M. (2019). A multifaceted risk model of brucellosis at the human–animal interface in

Egypt. *Transboundary and Emerging Diseases*, *66*(6), 2383-2401. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/tbed.13295?download=true

Abdellrazeq, G., Elnaggar, M., Osman, H., Davis, W., & Singh, M. (2016). Prevalence of bovine tuberculosis in Egyptian cattle and the standardization of the interferon-gamma assay as an ancillary test. *Transboundary and Emerging Diseases*, *63*(5), 497-507.

Aden, M. O., & Tukue, T. (2021). An overview on Bovine Tuberculosis and its economic significance. *Interdisciplinary Journal of Applied and Basics Subjects*, *1*(11), 1-15.

Arıkan, F. (2009). *Web GIS based animal diseases surveillance system* Middle East Technical University].

Bagheri Nejad, R., Krecek, R. C., Khalaf, O. H., Hailat, N., & Arenas-Gamboa, A. M. (2020). Brucellosis in the Middle East: Current situation and a pathway forward. *PLoS neglected tropical diseases*, *14*(5), e0008071. https://journals.plos.org/plosntds/article/file?id=10.1371/journal.pntd.0008071&type=printable

Borba, M., Stevenson, M., Gonçalves, V., Neto, J. F., Ferreira, F., Amaku, M., Telles, E. O., Santana, S., Ferreira, J., & Lôbo, J. (2013). Prevalence and risk-mapping of bovine brucellosis in Maranhão State, Brazil. *Preventive veterinary medicine*, *110*(2), 169-176.

Borham, M., Oreiby, A., El-Gedawy, A., Hegazy, Y., Hemedan, A., & Al-Gaabary, M. (2022). Abattoir survey of bovine tuberculosis in tanta, centre of the Nile delta, with in silico analysis of gene mutations and protein–protein interactions of the involved mycobacteria. *Transboundary and Emerging Diseases*, *69*(2), 434-450.

Boschiroli, M.-L., Foulongne, V., & O'Callaghan, D. (2001). Brucellosis: a worldwide zoonosis. *Current opinion in microbiology*, *4*(1), 58-64.

Churchyard, G., Kim, P., Shah, N. S., Rustomjee, R., Gandhi, N., Mathema, B., Dowdy, D., Kasmar, A., & Cardenas, V. (2017). What we know about tuberculosis transmission: an overview. *The Journal of infectious diseases*, *216*(suppl_6), S629-S635. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5791742/pdf/jix362.pdf

Corbel, M. J. (1997). Brucellosis: an overview. *Emerging infectious diseases*, *3*(2), 213. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2627605/pdf/9204307.pdf

Cutler, S., Whatmore, A., & Commander, N. (2005). Brucellosis–new aspects of an old disease. *Journal of applied microbiology*, *98*(6), 1270-1281. https://academic.oup.com/jambio/article-abstract/98/6/1270/6722197?redirectedFrom=fulltext

De Garine-Wichatitsky, M., Caron, A., Kock, R., Tschopp, R., Munyeme, M., Hofmeyr, M., & Michel, A. (2013). A review of bovine tuberculosis at the wildlife–livestock–human interface in sub-Saharan Africa. *Epidemiology & Infection*, *141*(7), 1342-1356.

Dean, A. S., Crump, L., Greter, H., Schelling, E., & Zinsstag, J. (2012). Global burden of human brucellosis: a systematic review of disease frequency. *PLoS neglected tropical diseases*, *6*(10), e1865. https://journals.plos.org/plosntds/article/file?id=10.1371/journal.pntd.0001865&type=printable

Decker, D. (2001). *GIS data sources*. John Wiley & Sons.

Durr, P., & Gatrell, A. (2004). *GIS and spatial analysis in veterinary science*. CABI publishing.

El-Ghitany, E. M., Omar, S. R., Abaza, A. M., Hassan, E. M., & El-Wahab, E. W. A. (2014). Trends in the epidemiology of brucellosis in a highly afflicted region in Egypt: A 16 year experience (1997-2012). *International Journal of TROPICAL DISEASE & Health*, *4*(2), 250-271.

Elmonir, W., & Ramadan, H. (2016). " Abattoir Based Prevalence, Economic Losses and Veterinarians' High-Risk Practices Survey of Bovine Tuberculosis in Mid-Delta of Egypt". *Alexandria Journal of Veterinary Sciences*, *49*(2).

Elsayed, D. S., Al Salahy, M. M., Hibah, N. A. A., El Mehy, G. F., Essawy, T. S., & Eldesouky, R. S. (2015). Evaluation of primary health care service participation in the National Tuberculosis Control Program in Qalyubia Governorate, Egypt. *Egyptian Journal of Chest Diseases and Tuberculosis*, *64*(4), 921-928.

Elsohaby, I., Ahmed, H., El-Diasty, M., Elgedawy, A., Mahrous, E., & El Hofy, F. (2020). Serological and molecular evidence of Mycobacterium bovis in dairy cattle and dairy farm workers under the intensive dairy production system in Egypt. *Journal of applied microbiology*, *129*(5), 1207-1219. https://academic.oup.com/jambio/article-abstract/129/5/1207/6714962?redirectedFrom=fulltext

Fitzgerald, S., & Kaneene, J. (2013). Wildlife reservoirs of bovine tuberculosis worldwide: hosts, pathology, surveillance, and control. *Veterinary pathology*, *50*(3), 488-499.

Garcia-Saenz, A. (2015). *Spatial epidemiology of bovine tuberculosis in domestic animals and evaluation of surveillance*. Universitat Autònoma de Barcelona.

Glaziou, P., Falzon, D., Floyd, K., & Raviglione, M. (2013). Global epidemiology of tuberculosis. Seminars in respiratory and critical care medicine,

Hamed, Y. K., Nasr, E., Azooz, M. F., & Youssef, H. M. (2021). Prevalence and risk factors of bovine tuberculosis in dairy cattle farms in Egypt. *Iraqi Journal of Veterinary Sciences*, *35*(2), 351-359.

Hegazy, Y., Molina-Flores, B., Shafik, H., Ridler, A., & Guitian, F. (2011). Ruminant brucellosis in upper Egypt (2005–2008). *Preventive veterinary medicine*, *101*(3-4), 173-181.

Hegazy, Y. M., Moawad, A., Osman, S., Ridler, A., & Guitian, J. (2011). Ruminant brucellosis in the Kafr El Sheikh Governorate of the Nile Delta, Egypt: prevalence of a neglected zoonosis. *PLoS neglected tropical diseases*, *5*(1), e944. https://journals.plos.org/plosntds/article/file?id=10.1371/journal.pntd.0000944&type=printable

Holzer, K., El-Diasty, M., Wareth, G., Abdel-Hamid, N. H., Hamdy, M. E. R., Moustafa, S. A., Linde, J., Bartusch, F., Sayour, A. E., Elbauomy, E. M., Elhadidy, M., Melzer, F., & Beyer, W. (2021). Tracking the Distribution of Brucella abortus in Egypt Based on Core Genome SNP Analysis and In Silico MLVA-16. *Microorganisms*, *9*(9). https://doi.org/10.3390/microorganisms9091942

Humblet, M.-F., Gilbert, M., Govaerts, M., Fauville-Dufaux, M., Walravens, K., & Saegerman, C. (2010). New assessment of bovine tuberculosis risk factors in Belgium based on nationwide molecular epidemiology. *Journal of clinical microbiology*, *48*(8), 2802-2808. https://journals.asm.org/doi/pdf/10.1128/jcm.00293-10?download=true

Kasir, D., Osman, N., Awik, A., El Ratel, I., Rafei, R., Al Kassaa, I., El Safadi, D., Salma, R., El Omari, K., & Cummings, K. J. (2023). Zoonotic tuberculosis: a neglected disease in the Middle East and North Africa (MENA) region. *Diseases*, *11*(1), 39. https://mdpi-res.com/d_attachment/diseases/diseases-11-00039/article_deploy/diseases-11-00039.pdf?version=1677656364

Khalafallah, S., & Zaki, H. (2020). Some epidemiological studies on brucellosis in dairy farms in Gharbia governorate. Egypt. *Benha Veterinary Medical Journal*, *39*(2), 15-19.

Khoshnood, S., Pakzad, R., Koupaei, M., Shirani, M., Araghi, A., Irani, G. M., Moradi, M., Pakzad, I., Sadeghifard, N., & Heidary, M. (2022). Prevalence, diagnosis, and manifestations of brucellosis: A systematic review and meta-analysis. *Frontiers in Veterinary Science*, *9*, 976215. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9813401/pdf/fvets-09-976215.pdf

Kim, C.-H., Choi, Y.-J., Lee, S.-H., Han, D.-H., Roh, Y.-H., Lee, D.-B., Cho, J.-H., & Kim, C.-H. (2023). Incidence of bovine tuberculosis and Brucellosis in Hanwoo (Korean native cattle) and dairy cow in Gyeonsangnam-do province from 2020 to 2022. *Korean Journal of Veterinary Service*, *46*(1), 67-74.

Kock, R., Michel, A. L., Yeboah-Manu, D., Azhar, E. I., Torrelles, J. B., Cadmus, S. I., Brunton, L., Chakaya, J. M., Marais, B., & Mboera, L. (2021). Zoonotic tuberculosis–the changing landscape. *International Journal of Infectious Diseases*, *113*, S68-S72. https://www.ijidonline.com/article/S1201-9712(21)00177-6/pdf

Lee, J.-C., Baek, Y.-B., Park, J.-G., & Park, S.-I. (2023). Prevalence and co-infection status of brucellosis and tuberculosis in Hanwoo in Jeonnam province. *Korean Journal of Veterinary Service*, *46*(4), 283-291.

McKenzie, J. S. (2004). The use of GIS in the management of wildlife diseases. In *GIS and spatial analysis in veterinary science* (pp. 249-283). CABI Publishing Wallingford UK.

MedicineNet. (2023). https://www.medicinenet.com/prevalence/definition.htm (accessed Febraury 10, 2023).

Mengistu, T., & Haile, A. (2017). Review on the application of geographical information systems (GIS) in veterinary medicine. *Int J Vet Health Sci Res*, *5*(4), 176-182.

Mugambi, J., Omwenga, S., Wesonga, H., Mbatha, P., Gathogo, S., Chota, A., Magwisha, H., Makondo, Z., Rukambile, E., & Mwakapuja, R. (2016). Bovine tuberculosis in east Africa. *African Crop Science Journal*, *24*(1), 53-61.

Nagy, G., & Wagle, S. (1979). Geographic data processing. *ACM Computing Surveys (CSUR)*, *11*(2), 139-181.

Nasr, E., Fawzy, R., Marian, G., Abbas, A., & Khalifa, E. (2021). Using of gamma interferon γ-IFN and multiplex PCR (m-PCR) for detection of bovine tuberculosis in dairy herds in Egypt.

Nasr, E. A., OR, S., & AM, S. (2019). Prevalence Of Bovine Tuberculosis In Different Cattle Breeds In Dairy Farm In Egypt. *Journal of Applied Veterinary Sciences*, *4*(2), 45-51.

Naugle, A. L., Schoenbaum, M., Hench, C. W., Henderson, O. L., & Shere, J. (2014). Bovine tuberculosis eradication in the United States: a century of progress. *Zoonotic tuberculosis: Mycobacterium bovis and other pathogenic mycobacteria*, 235-251.

Nerlich, A. G., & Lösch, S. (2009). Paleopathology of human tuberculosis and the potential role of climate. *Interdisciplinary perspectives on infectious diseases*, *2009*(1), 437187.

Neto, J. S. F., da Silveira, G. B., Rosa, B. M., Gonçalves, V. S. P., Grisi-Filho, J. H. H., Amaku, M., Dias, R. A., Ferreira, F., Heinemann, M. B., & Telles, E. O. (2016). Analysis of 15 years of the National Program for the Control and Eradication of Animal Brucellosis and Tuberculosis, Brazil. *Semina: Ciências Agrárias*, *37*(5Supl2), 3385-3402.

Norstrøm, M. (2001). Geographical Information System (GIS) as a tool in surveillance and monitoring of animal diseases. *Acta Veterinaria Scandinavica*, *42*(Suppl 1), S79.

Nossair, M., Eid, A. E. M., & Shaaban, S. (2021). A survey of some zoonotic diseases in cattle slaughtered at local abattoir, Behera Governorate. *Damanhour Journal of Veterinary Sciences*, *6*(1), 7-10.

Nour, M. O., & Nour, S. O. (2024). Systematic review and meta-analysis of the prevalence, incidence and treatment outcomes of tuberculosis in Egypt: updated overview. *Eastern Mediterranean Health Journal*, *30*(1).

Pereira, A. C., Reis, A. C., Ramos, B., & Cunha, M. V. (2020). Animal tuberculosis: Impact of disease heterogeneity in transmission, diagnosis and control. *Transboundary and Emerging Diseases*, *67*(5), 1828-1846. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/tbed.13539?download=true

Seleem, M. N., Boyle, S. M., & Sriranganathan, N. (2010). Brucellosis: a re-emerging zoonosis. *Veterinary microbiology*, *140*(3-4), 392-398.

Tschopp, R., Abera, B., Sourou, S. Y., Guerne-Bleich, E., Aseffa, A., Wubete, A., Zinsstag, J., & Young, D. (2013). Bovine tuberculosis and brucellosis prevalence in cattle from selected milk cooperatives in Arsi zone, Oromia region, Ethiopia. *BMC veterinary research*, *9*, 1-9.

Tschopp, R., Bekele, S., Moti, T., Young, D., & Aseffa, A. (2015). Brucellosis and bovine tuberculosis prevalence in livestock from pastoralist communities adjacent to Awash National Park, Ethiopia. *Preventive veterinary medicine*, *120*(2), 187-194.

Une, Y., & Mori, T. (2007). Tuberculosis as a zoonosis from a veterinary perspective. *Comparative immunology, microbiology and infectious diseases*, *30*(5-6), 415-425.

Youssef, A., & Ahmed, A. (2014). Bovine tuberculosis survey based on meat inspection and microscopic examination in central city abattoir in Ismailia, Egypt and its hazards to the abattoir workers. *International Food Research Journal*, *21*(2).

Zhang, N., Huang, D., Wu, W., Liu, J., Liang, F., Zhou, B., & Guan, P. (2018). Animal brucellosis control or eradication programs worldwide: a systematic review of experiences and lessons learned. *Preventive veterinary medicine*, *160*, 105-115.

Zhang, N., Zhou, H., Huang, D.-S., & Guan, P. (2019). Brucellosis awareness and knowledge in communities worldwide: A systematic review and meta-analysis of 79 observational studies. *PLoS neglected tropical diseases*, *13*(5), e0007366. https://journals.plos.org/plosntds/article/file?id=10.1371/journal.pntd.0007366&type=printable

Zinsstag, J., Schelling, E., Roth, F., Kazwala, R., Thoen, C., & Steele, J. (2006). Economics of bovine tuberculosis. *Mycobacterium bovis infection in animals and humans*, *2*, 68-83.

Zou, D., Zhou, J., & Jiang, X. (2018). Diagnosis and management of spinal tuberculosis combined with brucellosis: A case report and literature review. *Experimental and Therapeutic Medicine*, *15*(4), 3455-3458. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5840937/pdf/etm-15-04-3455.pdf