SOFIA UNIVERSITY “ST. KLIMENT OHRIDSKI”

FACULTY OF GEOLOGY AND GEOGRAPHY

Department of Regional and Political Geography

“Regional analysis of infectious diseases territorial distribution of livestock at the south borderline territory of Bulgaria”

EXTENDED ABSTRACT

of dissertation for acquiring the

educational and science degree “Doctor”

in a professional field 4.4. Earth Science, PhD program

Economic and Social Geography – Regional Development of Industrialization

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Enrolled by order № РД20-141/18.01.2019 г.

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Sofia, 2023

The dissertation is discussed and scheduled for defense in an extended department meeting of "Department of Regional and Political Geography", Faculty of Geology and Geography, Sofia University "St. Kliment Ohridski", which was held on 23.01.2023.

The public defense will be on 29.05.2023 (Monday), hall 2, at 1 p.m. in Sofia University "St. Kliment Ohridski".

The work materials are available at the dean's office of Faculty of Geology and Geography, room 254, north wing of Sofia University "St. Kliment Ohridski", 15 Tsar Osvoboditel boulevard.

CONTENTS

A. COMMON FEATURES OF DISSERTATION WORK

1. Relevance of the Topic

The importance of the topic comes from several reasons which can be divided into two groups. The first group is related to the economic consequences for the livestock sector and the regions where it develops, because of the introduction, spread and attempts to control infectious diseases in farm animals. Economic damages caused by various infectious diseases can be divided into direct and indirect. Direct losses are related to the measures taken to control the diseases. These include eradication, disinfection, veterinary medical expenses, payment of benefits and others. The second type of economic damages are indirect. They include the market and commercial losses of the participants in the agro-industrial and trade chain. Restrictions on trade in animals and animal products are the most obvious, but there is an even more complex causal chain. In fact, infections in farm animals can affect the balance between supply and demand, which reflects in the corresponding increase or decrease in prices, modifies the economic climate, and directly affects the prices of access to food for the whole society.

The second aspect of the actuality are the social consequences of the territorial diffusion of infectious diseases in farm animals. Many households that develop subsistence farms or small farms are affected, as a basic percentage of their income, is eliminated with the emergence and registration of infections. The phenomenon “subsistence farming” still exist in Bulgaria, which contributes with food products many households. Animals are reared in conditions that often do not provide a sufficiently high level of biosecurity, which makes them vulnerable to infection. When registering a case, a rapid eradication of the positive and contact animals is necessary, followed by difficult to control social problems. With insufficient awareness and knowledge on the part of the owners, they do not report the cases because they do not recognize the symptoms. Another part of the unannounced cases is due to deliberate actions on the part of the farmers, caused by fear related to the recent restrictions or by social coercion (poverty). In this way, the Bulgarian livestock sector is exposed to a high risk of infectious' spread to levels that can hardly be controlled.

The topicality of the topic stems from the fact that Bulgaria is exposed to more and more infections of farm animals, many of which entering from neighboring countries. With the ease of communication, the advancement of transport technologies, and the international trade space shrink, favorable conditions are created for the diffusion of diseases. More and more diseases are being registered in the country, which have either never entered the territory before or, at least, are atypical for it. In recent years, this has been more intense, and the process is both for the Bulgarian economic and social life at the regional and state level.

The present dissertation work is an attempt to thoroughly examine the diffusion of diseases in farm animals bearing in mind the need for an interdisciplinary analysis approach, which is found in the face of medical geography.

2. Object and Subject of the Study

The object of this research is the territorial diffusion of selected infectious diseases among farm animals in Bulgaria, namely African swine fever, Contagious nodular dermatitis, and Bluetongue, which exert socio-economic pressure on our country and are atypical from the historical perspective.

The subject of the study is conditions of spread that affect the characteristics of pathogens, hosts, and the environment, as well as their interrelationship with the spread of infectious diseases among farm animals on the territory of the country, with an overview of the southern border territories of the Republic of Bulgaria.

3. Purpose and Tasks of the Study

The purpose of the dissertation work is to make a regional analysis of the spread of infectious diseases among farm animals and to consider the trends in their diffusion in a broader sense on the territory of the entire country, in a narrower sense in the southern border territories of Bulgaria, as the factors influencing the diffusion of infectious diseases and their territorial distribution are studied.

To achieve the formulated goal, tasks have been added to this work:

- To clarify the place of medical geography among other sciences, the role of the study of epidemiological processes, as well as the conceptual and terminological apparatus for the needs of interdisciplinary research.

- To investigate the influence of the geographical location and environment in medico-geographic research and how they affect the diffusion of infectious diseases in farm animals.
- To study the diffuse processes in the epidemic waves by analyzing the connections between the elements of the epizootic process.
- To analyze the territorial distribution of the specific disease and to reveal the dependencies in their course.
- To determine and propose improvements in the control measures of infectious diseases in farm animals in Bulgaria.

4. Main Hypothesis

With the help of a comprehensive review of theoretical and empirical information based on conducting analysis and tracking the peculiarities of the diffusion of infectious diseases in farm animals, the dissertation seeks an answer to the question: "*Up to what extent, the connections between geographical factors which help the diffusion of infectious diseases in farm animals and the characteristics of epizootic waves are taken into account in the measures to control, limit and eliminate infectious diseases in farm animals in our country*?"

5. Methods and Methodology, Information Resources

Different methods and approaches were used in the research, depending on the specifics of the task and the specifics related to it, the object, the available information resources, the type of researched data, etc. The complex, spatial, and systemic approaches are strongly represented in the presented work in addition to the historical method.

The theoretical foundation on which the dissertation is based was compiled because of a study of the works of Bulgarian and foreign authors, from those who worked in ancient times to others who worked in modern times. The information provision is thanks to data from the Bulgarian Ministry of Agriculture. Information is used, also from World Organization for the Protection of Animal Health, the European Food Safety Authority, and other sources.

6. Geographic Range

Southern border territories are a concept that, depending on the research objectives, can change its geographical boundaries. In the most general sense, it includes all areas with borders that match the country's southern border. They are with Turkey and Greece – the first order of a neighborhood. Namely, within the limits of the Southwest region – Blagoevgrad municipalities, from the Southcentral region – the municipalities of Smolyan, Kardjali, and Haskovo, and the Southeast region – Yambol and Burgas municipalities. Because of the diffuse nature of the investigated phenomena, which are not limited to the indicated areas and the available information resources, was considered the entire country territory.

7. Structure of the Dissertation Work

The dissertation consists of an introduction, three chapters, and a conclusion with a total volume of 212 pages. Lists of references, appended tables and figures, and appendices are included outside the indicated pages. The bibliographic reference consists of 110 sources in Cyrillic and Latin. In addition, 16 Internet addresses are listed. The dissertation contains 43 figures, 13 tables, and four appendices.

B. DISERTATION STRUCTURE

INTRODUCTION

The relevance of the topic is justified in the introduction. The object and subject of research are determined. The goal is specified, as well as the necessary tasks to fulfill it. The hypothesis of the dissertation work has been drawn up. The methods used, as well as the geographical scope of the conducted research, are indicated.

CHAPTER FIRST. THEORETICAL FOUNDATION OF REGIONAL RESEARCH OF DISEASE DIFFUSION

The first chapter examines the essence of medical geography and its role in the disease's diffusion study, including those concerning animal populations. To shed light on medical geography's importance, its improvement from ancient times to the present day is examined. The medical geography terminology is summarized and defined. It is used in chapters two and three. The medico-geographical research methodology and its adjacent quantitative and qualitative methods have been considered. Also, the place of the region in conducting medico-geographic research is analyzed.

1.1 Essence, Subject and Purpose of Medical Geography

1.1.1. Essence of Medical Geography

The definition of medical geography should be as simplified as possible and, at the same time, not omit essential elements. Medical geography is a science that combines the knowledge, methods, and approaches of geography and medicine, using the scientific knowledge of other sciences (economics, statistics, sociology, etc.). It studies the dependence of manifested and potential diseases and their characteristics, such as occurrence, course, and elimination according of environmental factors. Medical geography studies these regularities in all living beings and on the entire planet territory. It is a weapon for our better understanding of the phenomenon of "disease" and helps to prevent it.

In 1952, at the Congress of the International Geographical Union in Washington, a definition of medical geography was given by a committee for the purpose. The definition they formulated is as follows: “*Medical geography is the study of geographical factors concerned with cause and effect of health and diseases*”.

1.1.2. Purpose and Subject of Medical Geography

The purpose of medical geography is to prolong and improve the quality of life of living beings by studying the interrelationships between disease and the environment. This is the main goal and unites all the tasks that should be solved when analyzing its subject.

One of the most famous theses defines the subject of medical geography as a set of relationships in the triad of population, environment, and culture. In determining the subject of medical geography, it is essential not to overlook diseases affecting animals. Several factors and conditions predetermine this importance – animal diseases are often zoonoses, the study of contagious diseases helps to understand the course of diseases in humans as well, humanity needs more and more food resources, animal diseases cause significant economic damage and finally, animal diseases are of interest to a group of narrow specialists.

1.1.3. Emergence and Development of Medical Geography

1.1.3.1. Medical Geography – an Overview

Medical geography is a science that studies the occurrence and spread of diseases, the development of which is a function of cause-and-effect relationships with the geographical factors of the environment that directly or indirectly influence their spread.

This short definition can be examined in detail, and each of its words is an element of additional scientific research in which many other terminological and methodological concepts are hidden. The reason for this broad subjectivity is rooted in two main facts. The first is that, under general cognitive forms, the science of medical geography has existed since the birth of philosophical knowledge in antiquity. At the same time, its realized and recognized place in the field of study was defined very recently in the twentieth century. The second fact lies in the essence of medical geography. Its very name indicates transdisciplinarity. That is why it is recognized separately by physicians and geographers as "their" subfield of science.

1.1.3.2. Medical Geography – Chronological Development

From ancient times people started to notice that environmental conditions influenced diseases. The first main works from antiquity that touch on the subject are those of Hippocrates (460 BC – 377 BC). He looks for the connections between environmental factors (water, food, climate, etc.) and the appearance of pathological processes. Later, other scientists such as Galen, Strabo, and Avicenna enriched and developed the theory of the connections between the course of diseases and environmental characteristics.

The great geographical discoveries marked the beginning of the Renaissance and, respectively, the New Age, which also included new biological dangers. "The shrink" of the geographic space reflects upon our health. Despite diseases conquering new territories and against the background of raging epidemics of plague, the Renaissance still brought development. In the last decades of the 17th century, scientists from England, France, and Italy became interested in the search for connections between diseases and the environment. Lots of analyzes have been conducted, many papers have been written, and the difficulties facing medical geography have been defined, all of which have become the subject of heated scientific debates.

1.1.3.3. Development of Veterinary Medical Geography

Veterinary geography is directly related to medical geography, as it uses its concepts and has the same tasks and goals. Veterinary scientists and practitioners themselves contributed in the past mainly through the development of epizootiology. In many aspects, epizootiology and medical geography overlap, although there are also differences. "*Their common goal was to understand the old and new diseases, to restrict them, and ultimately to limit future outbreaks*." Vishlenkova wrote, referring to the two scientific disciplines.

1.1.4. Definitions, Terminology and Connections between Medical Geography and Epizootiology

Like any science, medical geography has a set of definitions. What distinguishes medical geography is the free assimilation of terms from different sciences. That’s why it is a phenomenon created as a result of combining the approaches, methodology, and perspectives of these disciplines. The main things that medical geography looks at are disease, health, and their location in space.

There is a need for clarification of definitions that are an inevitable part of medical geography. Although many are borrowed from other sciences, it uses them freely, as mentioned.

A small part of them is a parasite, host, infection, vector, clinical picture, latent period, forms of the disease process, zoonosis, and others.

Many of the listed terms are widely used by epizootiology. The discipline has a broad range of contact points with medical geography. Epizootiology is a science that studies the patterns and determinants (determining factors) of the occurrence and development of disease in the animal population (Ivanov et al., 2013, p. 21). Epizootiology possesses characteristics that differ from clinical medicine and approaches medical geography.

1.1.5. Research Methodology

Research approaches used in medical geography can be divided into quantitative, qualitative, and combined. The differences stem from the type of data, how it is processed, the level of subjectivity in conclusions, and other characteristics. The methods are suitable for solving different tasks and complement each other to achieve the set scientific goals.

1.1.5.1. Qualitative methods

Qualitative methods use information that is difficult to represent through numerical values. It is worked with data that is easier to be described with words. Qualitative methods are fundamental in studying living beings, behavior, and decision-making.

The **narrative study** uses personal narratives that represent the narrator's experience of a past event or the present. **Phenomenological studies** are like narrative studies, but attention is focused on a group of individuals with similar life experiences related to a phenomenon. It is done through fixed questions. **Grounded theory research** explores the reality upon which creates a theory. **Historical research** is the systematic collection and analysis of historical information. The aim is to extract experience and trace causal relationships. **Case studies** focus on one specific case that is explored in depth.

1.1.5.2.Quantitative methods

"Quantitative methods" refers to systematic scientific studies of quantitative data and phenomena and their relationships through statistical approaches. One of the main quantitative methods that we will consider falls under the general name of geotechnics. Namely: spatial analysis and geographic information systems (GIS).

Spatial analysis is the study of locations and forms of geographic phenomena. And the relationships between them. Four measures are explored – point, line, area, and surface. It uses mapping and compares maps. Space is considered.

Another invariable part of quantitative methods is **Geographic information systems**. It creates models of reality by representing objects of the same type through layers. It uses georeferenced data and provides additional features for it. The type of data representation is through two models. Namely: a vector model and a raster model. The end product is maps that can be used in medical geography as a descriptive method answering the question *Where?*, and also as a method to seek answers to the question *Why?* And *How?*.

1.2. The Region-system in Medical Geography research

Humans, animals, and pathogens are in complex direct and indirect relationships with their habitats and each other. The region is an integral part of the course of epizootological processes. Knowledge of its characteristics is fundamental to the study of disease diffusion.

The classification of regions in medical geography is based on their various characteristics. In essence, these are homogeneous regions in the sense of P. Haggett. The more commonly used types are four – biomes, evolutionary regions, cultural regions, and natural foci.

The study of the region as a basic geographical unit in medical geography is easily understandable. In politically and economically separate countries, there are sometimes very diverse conditions for the disease (and not only). As Stoychev writes, "*The regional perspective confirmed the region as the main geographical unit of the study already at the beginning of the twentieth century. Areal differentiation needs a reasoned connection of different facts*".

1.3. Conclusions

As a result of the theoretical foundation's review of the regional study of diffusion, the hypothesis is confirmed that the study of the spread of diseases requires a multidisciplinary approach, finding expression in the face of medical geography, which has proven its effectiveness over the decades.

Complexity is achieved through the proposed theoretical approach, which examines the problem from various aspects. The complex and multidirectional connections between the region's peculiarities and the counteraction of diseases come to the fore. The comparison of the different approaches to regionalization in medical-geography research emphasizes the need for the careful composition of regions according to the set goals and objectives. The conclusion is valid considering the specific study and for disease prevention policies, control, and eradication at the municipal and national levels. Identification of regions can help in successfully achieving the set goals. This is done by clarifying the primary objectives of the adopted policies concerning infectious diseases in farm animals.

<u>CHAPTER SECOND. FACTORS AND CONDITIONS FOR LIVESTOCK DISEASE DISTRIBUTION</u>

The second chapter operates with the clarified terminological apparatus in the first chapter and aims to deepen the understanding of epizootic processes. The diffusion of infectious diseases in space is considered in its role as a part of diffuse processes in general. Special attention is paid to the characteristics of the elements of the epizootic process, namely – the pathogen, the host, and the environment, as well as the mechanisms of transmission and the relationships between them. Examined are the causality of diseases and the characteristics of the epizootic process. The analysis in the second chapter aims to deepen the scientific basis already created in the first chapter. The analytical approach in the third chapter is structured on it.

2.1. Space Diffusion of Infectious Disease

Diffusion is the process by which information, matter, or other phenomenon moves through the space between two points in a given time interval. Geography examines diffuse processes because they show some of the interactions between regions and, more specifically, the exchange between them.

Diffusion processes take place in two ways. The first is in the form of expansion, and the second is called relocation diffusion. In the case of **expansion**, the spread of the phenomenon is from point *x* to point *y*, and it continues to exist in the selected location. The expansion unfolds in two ways. When direct contact is necessary, it is called contagious diffusion. Examples are some infectious diseases. The second way of expansion diffusion is hierarchical. In it, the process of transmission proceeds from larger to smaller centers and is often referred to as cascade diffusion or vice versa – from small-scale to larger hierarchical centers.

The second type – relocation diffusion – is characterized by the passage of the diffusing phenomenon from point *x* to point *y*, simultaneously leaving its original location.

Hagerstrand laid the foundation for the various diffusion models by creating 12 rules. They are basic. According to the research's needs, they can be modified and complicated. The application of the model in practice is carried out by removing selected rules from it so that it corresponds to reality. It is also possible to add various barriers to limit the diffusion process, as in the case of epizootic processes.

Territorial diffusion models have been successfully applied in epidemic control. Different models have been developed that represent the process mathematically. One of the simplest methods divides the population into separate groups, namely – susceptible *S*, infected *I,* and recovered *R*.

2.2. Elements of Epizootic process

Modern epidemiology examines the participants in the epidemic process – the infectious agent and the susceptible individual. But also, transmission mechanisms, social and natural determinants. The epidemiological triad illustrates the epizootic process.

2.2.1. The Pathogen

The word "pathogen" comes from the Greek "*pathos*" – suffering and "*genos*" – birth, or in other words, the pathogen is the birth of suffering. Pathogens exhibit three prime forms of symbiosis. All three are varieties of parasitism in which one organism benefits from another while harming it – obligate, facultative, and opportunistic parasites. Since the pathogenic agent is a principal element in the study of infectious diseases' territorial diffusion, it is necessary to clarify its characteristics. Some of them are – infectivity, invasiveness, pathogenicity, virulence, toxigenicity, and others, as well as their related indices.

2.2.2. The Host

The host is the second important element of the epidemiological triad. He is the reason why medical geography and epidemiology exist as scientific units. Man himself, as well as animal species, are crucial in their role as hosts, and all efforts and studies are the results of the aspiration for their protection. Hosts can be considered with their individual characteristics – species affiliation, breed differences, age, sex, etc. and with their population characteristics – herd immunity, horizontal and vertical dynamics, etc. Coefficients and indices have been created that need to be taken into account. The characteristics of the host significantly influence the diffusion of infectious diseases.

2.2.3. Environment

Every phenomenon occurs in an explicit environment, and every organism exists in a definite habitat. Every process is affected by its surroundings. The environment is where life happens and the place where is fought the constant battle between life and death. It is not only a condition – but the environment also gives rise to life and has the power to terminate it. Its characteristics provide an advantage for pathogens or hosts.

The surrounding conditions can be divided into climatic, including the soil, and anthropogenic – a result of human activities. Climatic conditions are subdivided into macroclimate and microclimate. Macroclimate represents the natural climatic features. Microclimate is the specific features in a limited area and is much more susceptible to human influence. The environment influences hosts, pathogens, vectors, intermediate hosts, and the relationships between them.

2.2.4. Transmission Mechanisms and Connections between the Three Elements

The three elements of the epidemiological triad – pathogen, host, and environment are mutually connected and linked in the disease process at the individual level and in the epidemic process at the population level. As mentioned, their interaction is carried out by multidirectional modification of their qualities. In the transmission of the infectious process, three units are involved – *the source of the infection*, *the recipient of the pathogen*, and the *type of transmission mechanism* between them.

Sources can be divided into primary and secondary. A primary source of infection is an environment that allows pathogens to develop, multiply and spread successfully. The role of primary sources is infected animals and people with a given pathological agent. Animal production is also a vital and primary source of various infections. A secondary source is the soil, water, flora, and numerous objects related to the anthropogenic factor.

The transmission mechanisms of the infection are divided into two main types – direct and indirect. The difference between the two types is the need for the presence or absence of pathogens in the environment. They differ in the separation way of the pathogenic agent from the source, its residence in the environment, and paths of entering the recipient.

Recipients of the pathogens are the necessary elements for the successful continuation of the epidemic process. Important is not only its characteristics, such as species and individual sensitivity but also the physical possibility to carry out the transmission mechanism. Or in other words, favorable conditions must exist for the transmitter and the receiver to interact and for the transmission mechanism to proceed successfully.

2.3. Causation in Disease process

The main task of medical geography is to reveal how environmental conditions affect the spread of disease. In a broader sense, to contribute to the establishment of its causality. Causality is sought in the epidemic process and the occurrence of the disease process. As a result of the search for the latter, the postulates of Henle and Koch were created in the 19th century, and later the criteria of Hill and Evans (1965). One of the main differences between the two papers is the distinction between types of causality by Hill and Evans' criteria, based on which different causality models have been created.

There are several basic models of causality. The *epidemiological triad* is the classic model. Rothman's model considers component causes and is called the *Causal Pies Model*. He emphasizes that the cause of the disease is a combination of factors, which the author illustrates with pieces of a pie forming a whole. The third model is the *Network of Causes*, initially created to model chronic diseases. It's been successfully applied to polyetiological infectious diseases, as well. The fourth commonly used model that illustrates the causation of diseases is the *Wheel of Causation*. All models have their peculiarities, but their purpose is to clarify causality.

2.4. The Epizootic Process

The epizootic process is a series of infectious processes that follow one another. They are related to each other and develop within a population. According to the territorial scope, the number of infected hosts, and the typicality of its occurrence, the epizootic process is divided into epizootic, enzootic, and panzootic, and it may also be sporadic.

There are certain regularities during the epizootic process. Its characteristic is *self-regulation*. It is due to the complex interrelationships between the units that make it up. Six stages of the epizootic process are distinguished, which, although idealistically and theoretically separated, successfully delineate the ongoing processes at the affected population. Another fundamental characteristic of epizootic processes is cyclicity, which can be seasonal or periodic.

2.5. Conclusions

As a result of the analysis, several main conclusions can be drawn. Territorial diffusion of infectious diseases is essentially a diffuse process that can be theoretically considered as such and, therefore, subject to mathematical and statistical studies. Their goal is to generate models of the diffusion processes, which subsequently participate in attempts to predict the spread of diseases. By studying the diffusion characteristics, different types of barriers, including spatial and biological, can be applied to modify the process. The participation of the mentioned biological barriers is possible with comprehensive information about the characteristics of all components in the epizootic process, some of which are biological. The characteristics of the pathogen, the host, the environment, and the mechanisms of disease transmission are the source of risk factors for farm animals. Some of these features, however, are part of the answers to the questions – *What are the most appropriate preventive measures for the given type of disease? What are the weak links in pathogens protection and countering the epidemic? What are the spatial characteristics of the affected protected region?* and many more.

Based on the analysis, the hypothesis is confirmed that each disease process at the population level must be considered individually due to the very diverse characteristics of its constituent parts. In turn, this fact leads to the logical conclusion that the measures to protect against and reduce diseases must be regionally tailored to reality. And needs to be changed promptly about the variability of the disease diffusions.

The causality in epizootic processes and its search are the basis of the spread of infections. When defining the causality, the questions *How?, When?* and *Why?* are sought to be clarified in connection with the outbreak of epidemics. The answers to these questions are made up of biological, social, economic, political, environmental, and other components that are not traditionally "part" of medical science but cannot continue to be ignored.

CHAPTER THIRD. ANALYSIS AND TRENDS IN GEOGRAPHICAL DISTRIBUTION OF SELECTED LIVESTOCK INFECTIOUS DISEASE

In the third chapter, a regional analysis of the spread of three selected diseases among farm animals, which are relatively new for the country from a historical perspective, and their appearance leads to significant social and economic consequences, is made. The trends for their territorial diffusion were examined. For this purpose, because of the nature of the subject, their global spread was followed, especially the ways of entering the country. Due to the type of data, the geographical scope of the study, in a broader sense, is the entire territory of the country and, in a narrower sense, its southern border regions. The latter is the focus of the thesis due to their geographical location and the risk they may represent about the penetration and spread of infectious diseases from and to the southern neighboring countries.

3.1. African Swine Fever Disease

3.1.1. African Swine Fever Disease – an Overview

African swine fever is a highly contagious disease affecting domestic and wild pigs of all ages and breeds. Lethality reaches 100%. African swine fever virus is exceptionally durable in the environment. It is also stored virulent in fresh meat and various products of pig origin. The source of the disease, in addition to objects and food products, are the carcasses of dead animals, sick, and contact individuals. Entry of the virus into a host is by direct or indirect contact. The disease is not a zoonosis.

Since there is no approved vaccine, no effective treatment and the spread is rapid, and with a high fatality rate for infected animals, two strategies are relied upon. First – prevention of healthy herds and infection-free livestock facilities and territories, and second – elimination of the infection after its entry. The disease is a transboundary infection notifiable to the World Health Organization.

3.1.2. African Swine Fever Disease – World Territorial Diffusion

In 1921, Montgomery in Kenya recognized African swine fever as a new disease, distinct from classical swine fever. After 1927, the disease was recorded in several sub-Saharan countries. Its territorial diffusion can be traced from the middle of the twentieth century when it began to spread beyond the borders of the African continent.

In 1957, the virus left Africa and was found in Portugal, near Lisbon airport. Its mechanism of entry into the country is believed to be throughout feeding contaminated food waste from airplane flights to local pigs. When it first entered Portugal, the virus had a mortality rate of up to 99% among infected populations. After 1964, the infection was also recorded in other countries of Europe, South, and Central America, including island countries of the Caribbean basin. Due to the preparedness, the outbreaks were brought under control relatively quickly. After 1999, the African swine fever virus spread mainly on the territory of Africa, covering new regions that had not been affected until then.

After several years of seeming lull for the world, massive changes occurred in 2007 when a case was again registered outside the African continent, namely in the Caucasus region, specifically Georgia. It is assumed that the disease was imported into Georgia through infected meat or pork products from East Africa, as evidenced by the location of the outbreak – near the port of Poti. From that moment on, a rapid spread followed in neighboring countries – Armenia, Azerbaijan, and Russia. The spread of the disease has not been controlled on the territory of Russia and the Caucasus region. In 2012, the territorial entry of the virus began in the direction of Western Europe as follows: Ukraine – in 2012, Belarus – in 2013, Lithuania, Latvia, Estonia, and Poland (entering the EU) – in 2014, etc. In 2017, the disease affected Romania, and in 2018, the first case was recorded in Bulgaria.

3.1.3. African Swine Fever Disease – Territorial Diffusion in Bulgaria

The conducted regional analysis of the diffusion of African swine fever for the territory of Bulgaria is within two populations – wild pigs and domestic pigs. The analysis is within the respective years when the disease was registered in the country. The data includes the number of cases of infected animals, the number of dead infected, the total number of shot down, shot down infected, and slaughtered, and the number of both populations.

3.1.3.1. Regional Analysis and Trends of African Swine Fever Disease Diffusion in Domestic Swine

The first case of African swine fever in Bulgaria was registered in August 2018 in the village of Tutrakantsi, Varna region, on a backyard-type farm (natural farm). Although the entry of the virus into the country is not a surprise due to its presence in our northern neighbor, the first recorded outbreak is relatively far from our northern border, approximately 100 km. In a 2019 paper, Zani and his team explored possible hypotheses for the virus's entry into the Tutrakantsi farm, citing anthropogenic factors as the most likely cause.

The anthropogenic factor in such diseases as African swine fever is of chief importance for several reasons.

- The virus is durable in the environment.
- The pathogen remains in the carcasses of dead animals, their organs, secretions, and excretions. Isolation of carcasses from other pigs in the vicinity is of utmost importance. This feature is not observed in the specified farm.
- The addition of waste food components in the diet of farmed pigs poses a risk due to the survival of the pathogenic agent for a prolonged period in them.
- Providing contact between wild and domestic pigs is a risk factor influenced by human activity.
- The importation of pigs with unknown health status and the lack of precautions in its implementation is a prerequisite for virus entry into unaffected herds and territories.

All mentioned factors are substantial for the territory of Bulgaria because of the socioeconomic condition of pig farming. Natural farming facilities are 96% of all facilities where pigs are raised, making up 34% of the total population of farmed pigs.

For 2018, no more outbreaks were registered in domestic pigs. The re-emergence of the virus in domestic pigs is nearly a year later. But this re-emergence has seen primary outbreaks several days apart in three different regions. In connection with the almost simultaneous appearance of the disease in different locations in the country, we can form a hypothesis that after the initial penetration of the virus on Bulgarian territory, its subsequent spread was carried out mainly through wild pig populations. The hypothesis is also confirmed by the data we have on the spread of the disease among wild pig populations in the same one-year period between the first and second registration of the disease in domestic pigs.

After July 2019 and the second recorded outbreak of the disease in domestic pigs, its much more consistent territorial spread began. *Figure 22* indicates the registered cases of domestic pigs for the period 2019 – 2022.

In domestic pigs, the disease peak was in 2019, with the Ruse region leading the negative statistics with over 300 infected individuals, followed by the Silistra region. Both areas are situated next to the supposed country's external source – Romania. This makes the North Central region the region with the most domestic swine cases for 2019 and overall, to date. Peak levels in domestic pigs in Ruse and Silistra regions were accompanied by constant maintenance of disease levels among wild populations in 2019.

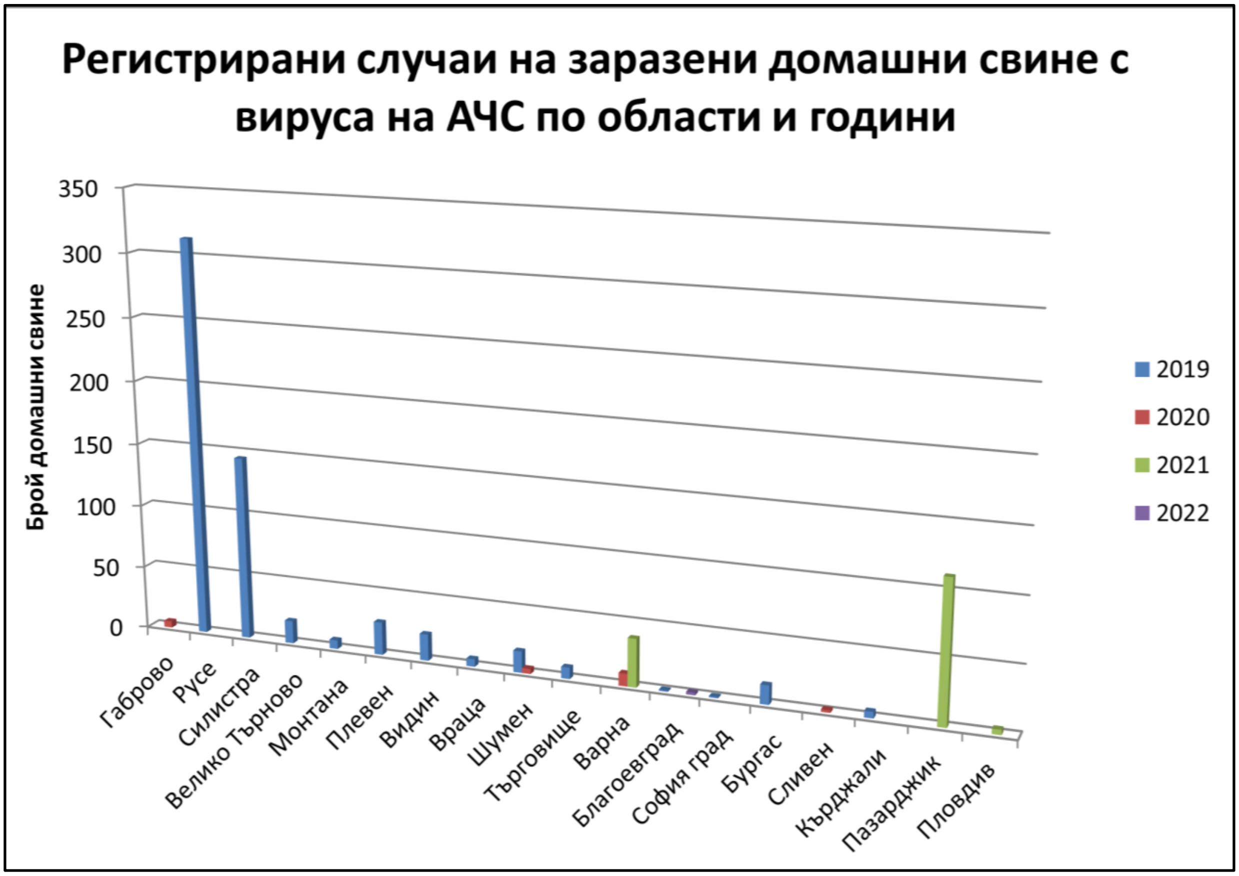

Figure 22 – Registered cases of infected domestic pigs with the ASF virus by regions and years. Only the areas with registered cases are marked on the graph. (Data by Ministry of Agriculture, Food and Forestry).

In 2020, the registered cases of domestic pigs were minimal. The only ones noted were in the Shumen, Varna, and Sliven districts. In the same year, wild populations were massively affected by the disease. And in 2021, the trend of the spatial-temporal relationship of the disease in wild and domestic populations is preserved.

A territorial spread of the African swine fever virus is observed in a large part of the areas. It diffuses towards the country's southern border, and as an outcome of its spread, every region is affected. The diffusion movement is diverse in the individual regions during the study time interval.

The necessary strict measures and high mortality are causing significant losses to the sector, with pig farming in 2019 marking a historic low in the number of farmed animals for the last twenty years.

3.1.3.2. Regional Analysis and Trends of African Swine Fever Disease Diffusion in Wild Swine

The first registered case of African swine fever in wild boar was on 18.10.2018 in the Silistra region. Once it enters the country, the infection begins its spread into neighboring territories.

Figure 26 shows the cases of infected wild boar from 2018 to 2022.

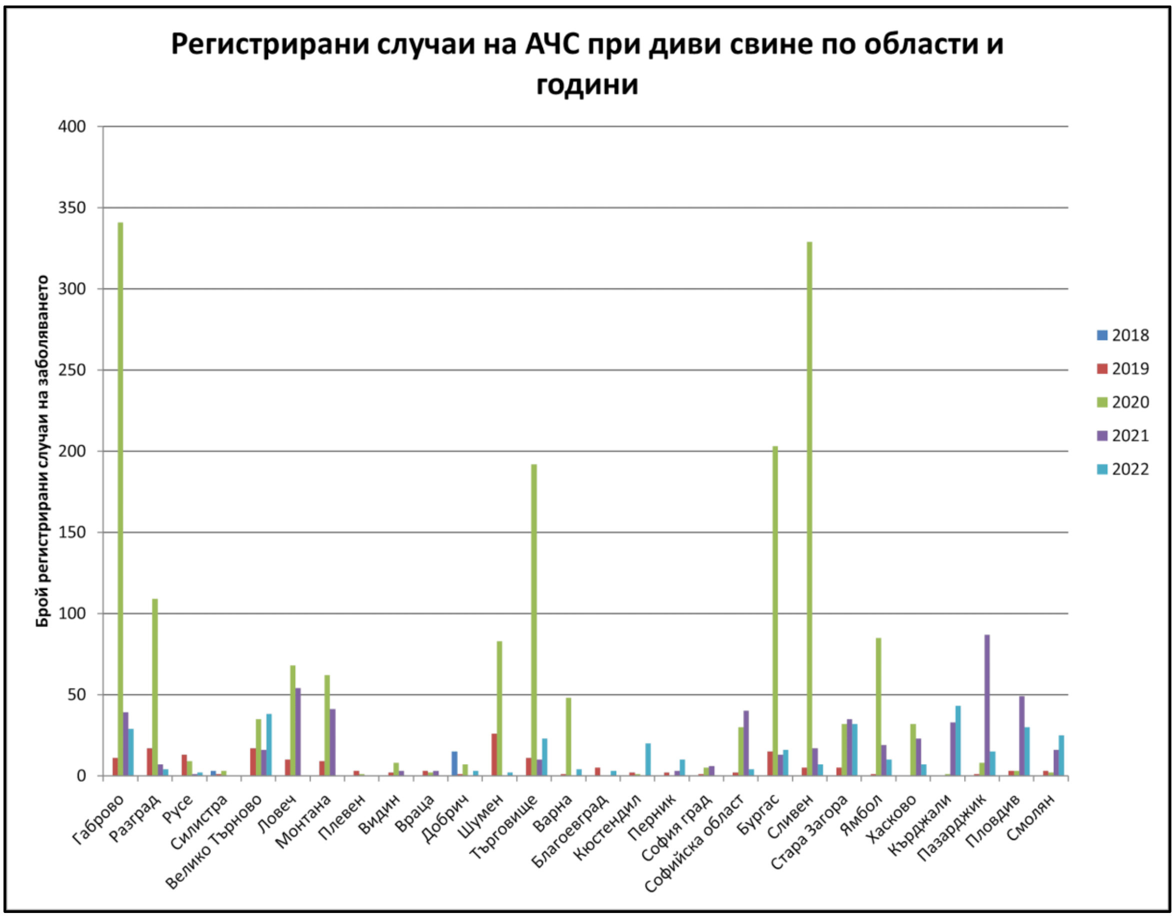

Figure 26 – Number of registered cases of African swine fever by region and year from 2018 to 2022 (Data by Ministry of Agriculture, Food and Forestry).

It is clear from the graph that in 2019 the diffusion began gradually to develop territorially. The most significant number of virus registrations are still in the country's northern parts, but cases are starting to appear relatively quickly in the southern regions. Moreover, in the peak year of the disease for wild boars – 2020, some of the most numerous cases are in the southern part of the country. In 2021, a significant drop in the number of reported cases was observed, which overall for the country maintained the downward trend in 2022 as well.

When examining the territorial spread of African swine fever in the four years by region and the corresponding measures taken to limit the disease, a relationship between the number of animals in the incubation period (killed infected), the severity of the measures, and their respective results are noticed.

When examining the southern regions of the country, specifically the southern border territories, it is noticed that although the disease entered from the north in 2018, the very next year, the first outbreaks were registered in the southern regions in both wild and domestic pigs. Moreover, in 2020, 2021, and 2022, the recorded number of infected wild boars peaked in the southern territories. In other words, the African swine fever virus shows a tendency of territorial spread to the south with a corresponding shift of the peak of cases to the southern regions.

3.1.4. Conclusions

From the analysis in the third chapter, we can draw several conclusions regarding the spread of African swine fever disease. As for the pathogen, it has such interactions with the environment that allow it to be transported over great distances through the anthropogenic factor. Measures to limit the disease should be aimed at the population and, more specifically, informing and educating them on the subject.

In the global and national spread of African swine fever, a "lull" was observed among domestic pigs after the initial entry into the specific territory, followed by a sudden peak in incidence. The reason is that the virus moves among wild boar populations during the quiescent period among domestic pigs. It was established that on the territory of the country, after the initial entry of the virus, the territorial-temporal relationship between the diseases in the wild and farmed populations of the hosts is preserved.

The analysis also revealed a correlation between the number of wild boars in the incubation period and those found dead, i.e., the animals with a fatal outcome. Because of this dependence are the different results of the same measures over the years. Or in other words, at morbidity lower levels, relatively stricter measures than those applied so far are necessary. At higher levels of morbidity, the same actions have given a distinctly positive result.

3.2. Lumpy Skin Disease

3.2.1. Lumpy Skin Disease – an Overview

Lumpy skin disease is a viral disease that affects beef and dairy cattle. Water buffaloes and other wild animals, which are not directly related to the spread of the disease on the country's territory, have also been infected. Other farmed animals and humans are not affected. Vaccines have been developed and approved and are administered according to the respective policies of the affected countries.

Some sources indicate morbidity from 5% to 50%, while others recall that it can reach 100% in affected herds. The main route of spread is through the vector mechanism of transmission, through the bite of insects such as certain types of mosquitoes, flies, and ticks. There is also evidence for a secondary mechanism of spread through objects as mechanical carriers of the virus and through direct contact between hosts.

Although Lumpy skin disease is not a zoonosis and does not have a high mortality rate in affected individuals, it is of great importance to the world's livestock industry due to the economic losses it causes. For this reason, the World Organization for Animal Health places Lumpy skin disease on the list of notifiable diseases.

3.2.2. Lumpy Skin Disease – World Territorial Diffusion

Lumpy skin disease of cattle was first recorded in 1929 in Zambia, South Africa. After that, it began to spread north and south of the state borders as an already recognizable disease. In 1957 it entered Kenya, where it was first described in detail. By 1988, the infection was spreading in Sub-Saharan Africa, but its movement was never controlled, and in the following years, it spread to more northern territories.

In 1988, the infection entered Israel, and since 2012, a rapidly spreading wave has been observed, affecting new territories, chronologically as follows – Lebanon, Jordan, and Iraq. Syria is also not thought to be free of the disease, and in 2013 the Lumpy skin disease virus was reported in Turkey. The following year, Iran and Azerbaijan were affected. Thus, the epidemiological map concerning the territorial extent of the disease in 2014 for Eastern Europe and Asia looks worrying. From 2012 to 2014, the infection managed to penetrate several countries in Asia and is near the borders of the European Union. In August 2015, 15 km from the nearest registered outbreak in Turkey, the disease's first cases were also on record in Greece, respectively, the European Union.

Despite the implemented measures and attempts to limit the disease, the diffuse wave continues its territorial movement on the territory of Greece. When tracking the spread of Lumpy skin disease in the country, spatial "jumps" are distinguished. The Ministry of Rural Development and Food in Greece notes that within approximately three months of the first disease's registration, 4,060 cattle died due to direct pathological changes from the sickness, or the measures taken. The lethality due to the virus in Greece for the specified months is 0.19%, and the morbidity is 9.2%.

The diffuse wave, which began in 2012 in Asia, and crossed several state borders until entering a member state of the European Union three years later, will not stop its movement here.

3.2.3. Lumpy Skin Disease – Territorial Diffusion in Bulgaria

On April 14, 2016, two primary outbreaks of Lumpy skin disease were simultaneously registered in Bulgaria. The outbreaks are in natural farms in the Haskovo district at about 2 km from each other but relatively far from the border with Greece – approximately 100 km. In the same period, opinions were expressed that the probability of the influence of the anthropogenic factor for the penetration of the disease on the territory of the country was high. The first outbreaks are near water bodies, a prerequisite for their subsequent spread through vectors. A rapid territorial diffusion of the disease was observed after its initial registration, and territorial jumps similar to those in Greece were noted. Also exists a possibility of repeated entry of the disease through our southern border due to the locations of the registered outbreaks.

Figure 33 shows cases of Lumpy skin disease by region and month. Two patterns of development of the disease diffusion are observed, and the head importance for them is the start of the vaccination program and, more specifically, the moment when the building of herd immunity begins.

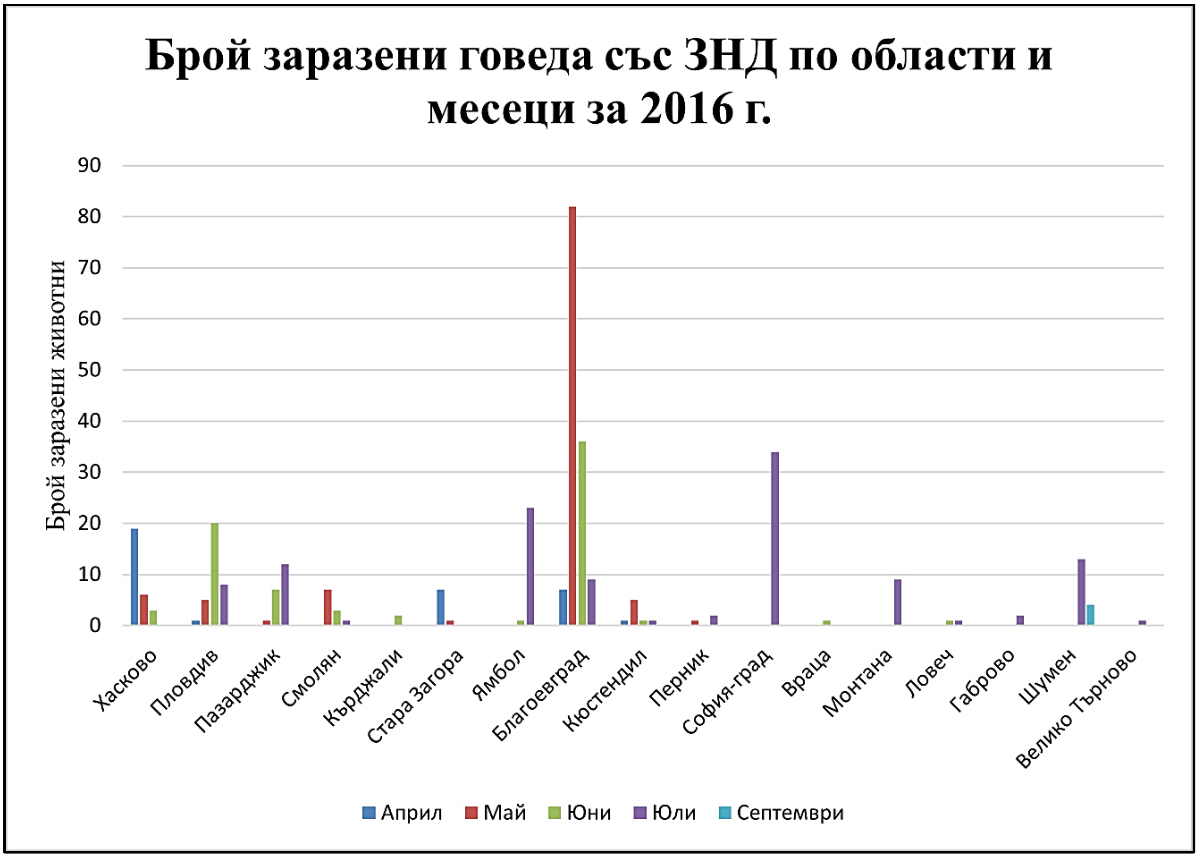

Figure 33 – Number of infected cattle with Lumpy skin disease by regions and months for 2016 in Bulgaria. Only the areas with registered LSD outbreaks are marked on the graph.

A dependence is found, which shows that for the penetration of the disease to new and relatively remote territories, the chief role is played by human activity, respectively the trade in animals, which is observed when the infection penetrates the country. But once in a favorable environment, the virus begins its spread through vectors simultaneously in multiple directions between individual herds that are relatively close to each other.

The tendency for relatively low levels of infected individuals compared to the number of susceptible individuals in all areas also comes to the fore. This fact again shows that the spread of the virus can cover large areas in a short period without invariably resulting in large numbers of infected cattle. However, due to the necessary measures to contain the disease, this does not mean less economic damage. In other words, even with one infected animal in the herd, the necessary measures predetermine its destruction, and because of this, the weight of the lost benefits.

The territorial diffusion of Lumpy skin disease in Bulgaria starts from the country's southern regions, spreading from southwestern and south-central Bulgaria to the country's northern territories.

We can summarize that in 2016, the epizootic wave that was observed, managed to reach all regions of the country within six months, affect many farms, and have an economic impact on the livestock sector.

3.2.4. Conclusions

Due to the presented analysis, we can draw several conclusions regarding the Lumpy skin disease. The disease has the potential for rapid territorial spread when entering new populations and favorable conditions.

Observed virus spatial "jumps" probably, related to anthropogenic activity, determine its appearance in places unexpectedly distant from the sources. In this regard, prevention measures limited to increased surveillance and testing of risk populations do not give satisfactory results. Vaccination is a justified and efficient measure for Lumpy skin disease prevention in the territory of Bulgaria in connection with its geographical location and the related epizootic risks of the disease.

Beneficial experience for the entire European Union can be gained from the Lumpy skin disease epizootic course in Bulgaria in 2016. The reason is mainly its geographical location and the possibility of cross-border diseases. As a country with those characteristics, Bulgaria faces a vast responsibility, firstly to its population and economy and secondly to those neighboring territories for which it may represent a bridge or a barrier to the diffusion of diseases.

3.3. Blue Tongue

3.3.1. Blue Tongue – an Overview

Bluetongue is a non-contagious viral infection transmitted by vectors of the genus *Culicoides*. Domestic and wild ruminants are infected – sheep, goats, cattle, buffaloes, deer, and other representatives of the wild fauna, some of which are uncharacteristic for the Bulgarian latitudes (camels, antelopes, etc.). Clinical manifestations mainly affect sheep of all ages and breeds. Cattle and goats are less frequently affected but are significant for epizootic dynamics due to their ability to act as asymptomatic sources for a prolonged period. As a representative vector-borne disease, the survival of the virus in nature as well as its spread directly depends on that of the insect vector.

A vaccine exists and is administered according to the policy adopted by the country. In addition to the direct losses to farmers caused by death, loss of production, and offspring from infected herds, the costs are added to the restriction of trade, veterinary and sanitary costs, and those for vaccines. Morbidity in susceptible individuals in areas new to the virus can reach 100%, and mortality varies between 2% and 70%. Bluetongue is not a zoonosis. The disease can cause devastating economic damage and is notifiable under the World Organization for Animal Health code.

3.3.2. Blue Tongue – World Territorial Diffusion

At the end of the 18th century, the disease was registered and identified in Africa. Until 1940, it was believed to be confined to the territories of South Africa, but within a short period, the virus was isolated in diverse and remote locations around the world. For this reason, today, it is believed that the virus was present in them as an unidentified pathogen. With the newly recorded cases, the range of the Bluetongue was outlined in broad limits. However, until 1998 they were limited to 40^{o} south latitude and 35^{o} north latitude, Bulgaria being respectively outside them. After that year, the disease entered through two corridors – eastern and western, in the direction of Europe, which are carriers of serotypes new to the continent.

By 2004, the disease covered a large percentage of the European continent. Several main diffuse waves have been observed, which first affect our southern neighbors – Turkey and Greece, and then the territories of our country. The first started in 1998, the second in 2006, and the most recent in 2014. The last one had the most severe economic and social consequences.

3.3.3. Blue Tongue – Territorial Diffusion in Bulgaria

As was noted, until 1998, the disease Bluetongue was considered exotic in Europe, including Bulgaria. With the entry of the virus into the European part of Turkey and Greece, the danger of its appearance in Bulgaria is significant. It became a reality in June 1999 with the registration of an outbreak in the village of Slivarovo, Burgas region.

Bulgaria is affected by the eastern wave, through which four new serotypes enter Europe – BTV-1, BTV-4, BTV-9, and BTV-16. In 1999, research showed that only one virus serotype occurs in our country, namely BTV-9. It was also isolated in Turkey and Greece. While the epizootic wave in 1999 covered exclusively the southern border territories, and the same one in 2001 exclusively the western border territories, in 2014, the infection managed to enter all regions of the country.

In 2014, almost simultaneously, outbreaks were registered in different areas, suggesting the introduction of the disease through Culicoides and not through a single importation of infected animals. In the same year, the Bluetongue epizootic developed on an unprecedented scale. Within just five months, from July to November inclusive, many outbreaks were registered, with multiple infected and dead individuals. The affected animals are predominantly sheep. It can be seen from *Figure 40* that the severity of the epizootic process gradually increased, reaching its peak in September.

Unlike in 1999, when the serotype isolated was BTV-9, in 2014, BTV-4 was isolated. From the data that we have and based on the analysis, a wider territorial spread of the latter and also significantly heavier economic damages are reported. Including a more severe impact on cattle and goats, although this is many times less than the observed effects on sheep farming. Comparing the two epizootic waves in the country from 1999 and 2014, higher mortality and morbidity can be observed in 2014. They are relatively close to those reported in Greece.

In the southern regions, where the infection entered the country and spread to the north, the vastest number of registered outbreaks and the most of case number of infected individuals were reported. Although the diffuse wave started from the southern border territories, which are closer to the known territorial extent of the disease – 35ºN, it managed to spread to the north, covering all regions. Moreover, the diffusion model remains uniform throughout the country.

Figure 40 – Clinically sick and dead ruminants in connection with the disease Bluetongue by month for 2014 in Bulgaria (data by Ministry of Agriculture, Food and Forestry).

3.3.4. Conclusions

Several conclusions can be drawn based on an analysis of the diffusion of the Bluetongue in Bulgaria. The country is exposed to repetitive risks of introduction of infection from southern neighboring countries, including a variety of serotypes, some of which can have increasingly severe consequences for agriculture historically. The virus keeps the tendency to expand its territorial range to the north, leaving its historical limits. The regional characteristics of the country provide the necessary conditions for maintaining an epizootic wave. The distribution pattern of the Bluetongue in Bulgaria remains uniform throughout the country, without significant differences being noticed in its southern and northern parts.

CONCLUSION

The dissertation contains three chapters, in the first of which an attempt is made to clarify the place of medical geography in the study of epizootic waves. And also the application of its approaches to the territorial analysis of the diseases spread. In the mentioned first chapter of the present work, special attention is paid to the benefits of the interdisciplinary approach. It contributes to better causal relationships understanding in diffuse waves of infectious diseases. The hypothesis is confirmed that the advantages of medical geography, proven over the decades, successfully combine the methodology of various scientific disciplines. Attention is paid to the multidirectional relationships between the characteristics of the studied region and the course of diseases. As a result of the analysis, the need for regions' expedient composition is highlighted.

The second chapter examines the elements of the epizootic process and the characteristics of the conditions under which it develops. The unity of the environment, with its social, economic, ecological, and other components, with those of the traditional elements of the epidemic chain – pathogen, host, and mechanism of transmission, is emphasized. The place of infectious disease diffusion, as one of the territorial diffuse types processes in general, is clarified and is considered an object of mathematical and statistical studies. Through them, and more specifically through the generation of models of diffusion processes, attempts to predict the spread of diseases are possible. The causality in epizootic processes and their search are the basis of the spread of infections. By determining the causality, clarification is achieved of the questions *How?*, *When?* and *Why?* in connection with the outbreak of epidemics. The answers to these questions are biological, social, economic, political, ecological, and other types of nature that are not traditionally "part" of medical science but cannot continue to be ignored.

Based on the foundation created in the first two chapters, a regional analysis of the spread of three infectious diseases among farm animals was conducted in the last third chapter.

For the first examined disease – the African swine fever – it was concluded that because of the relationship between the pathogen and the environment, the virus could be carried over long distances due to the influence of the anthropogenic factor. Based on this fact, the measures to limit the disease must also be aimed at the population, its information, and education on the subject. Once in a favorable environment, the epizootic wave is maintained through the wild populations of the hosts. Because of that factor, the spread of the African plague on a global scale, and in Bulgarian territory, a "lull" was observed among domestic pigs after the initial entry into the specific area, after which there was a sudden peak of morbidity. The dissertation established the territorial-temporal relationship between morbidity in domestic and wild pigs. A correlation was found between the number of wild boars in the incubation period and those that reached a lethal end. The result of this dependence is the different results of the same measures over the years. Or in other words, with lower levels of morbidity, relatively stricter measures are needed than those applied so far, while for higher morbidity levels, the same actions give a distinctly positive result.

The analysis of the second disease diffusion - Lumpy skin disease - confirms its potential for rapid territorial spread after entering a favorable environment. The pathogen also finds those conditions in the country's territory. Attention has been paid to the spatial "jumps" observed in its spread and their more likely connection with the anthropogenic factor. The stated hypothesis is confirmed that vaccination is a justified and efficient measure for the prevention of Lumpy skin disease for the country's territory in connection with its geographical location and the related epizootic risks of the disease.

Regarding the third disease – Bluetongue – it is concluded that although the country is a relatively new area for its diffusion, the current conditions of the region support the spread of the infectious process throughout its territory. The country is at risk of recurring epizootic waves. In this regard, the southern border territories are exposed to immediate risk and may become a source of disease for the rest of the country. The entry of new serotypes of the virus, some of which have the potential for even more considerable economic consequences, is also not excluded. Based on the analysis, the conclusion is reached that the epizootic diffusion occurs according to a set pattern, characteristic of the country's entire territory, without significant differences in its southern and northern regions.

The proposed dissertation aims to clarify the trends of territorial distribution of three selected diseases. It also seeks an answer to the question – "*Up to what extent the connections between geographical factors which help the diffusion of infectious diseases in farm animals and the characteristics of epizootic waves are taken into account in the measures to control, limit and eliminate infectious diseases in farm animals in our country*?". The characteristics of individual diseases, the way they progress, and the region peculiarities are considered in the applied measures, which is visible from the results for their limitation. Their improvement, however, is possible and necessary for faster achievement of results and less economic and social consequences for the country.

CONTRIBUTIONS

The contributions of the dissertation are concluded in:

- The modern place of medical geography, among other sciences, is clarified, and its role in the study of epizootic processes with pronounced medico-geographical characteristics is analyzed.

- The importance of the geographical position and environment in conducting medico-geographic research has been proven, including the specificity of the individual regions for the studied diseases.

- A regional analysis of economically and socially prominent epizootic processes is conducted, and measures that address both – socioeconomic and medical challenges are proposed.

Publications in connection with the dissertation work

- Gotsova, K., 2021. Medical geography in a contact zone between natural and social sciences. – In: Collection of reports from scientific conferences "Geography and regional development". LOPS Foundation.
- Gotsova, K., 2023. Analysis of territorial diffusion of bluetongue epizootic wave during 2014 in Bulgaria. – In: Annuaire de l'universite de Sofia "St. Kliment Ohridski", Faculte de geologie et geographie.