Epizootological geo-information systems

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Abstract. Geo-information technologies allow to conduct procedures for analysis and assessment of the risk of natural focal infections, including: assessment of the probability of biological and economic consequences of the spread; risk management; risk communication. Using software for risk analysis and assessment allows to standardize this process and to provide the transparency (evidence) of the procedure, when all data, methods, results and conclusions are documented automatically. The conclusions follow from statistically significant mathematical calculations. The architecture of the epizootological GIS can be extended to any number of nosological units (diseases), including those that are not part of the natural focal group. This makes it possible to use the epizootological GIS project as a risk management tool for all especially dangerous, transboundary, quarantine and socially significant diseases, both on the territory of Russia, and within the Customs Union and CIS countries.

1. Introduction

This article is a methodological guide designed to be used by researchers, epidemiologists, epizootologists, as well as employees of the Department of Veterinary Medicine, Federal Service for Veterinary and Phytosanitary Surveillance (Rosselkhoznadzor), Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing (Rospotrebnadzor) and health authorities.

The methodological guide is made to modernize the procedure for planning and carrying out anti-epizootical and anti-epidemic measures by introducing geo-information technologies.

Geo-information technologies (GIT) allow to process geographic (spatial) data which can be integrated with other types of data. This makes it possible to use GIT in a wide range of disciplines, including epizootical and epidemiological studies. The component of GIT is geo-information system [1-6].

Geo-information system (GIS) is a multi-functional information system designed to collect, storage, analysis as well as graphic display (visualize) spatial data and associated attributive information on electronic maps.

Electronic map (EM) or electronic geographical map is a digital cartographic model visualized or prepared for visualization on the screen of a geographical information display facility in a special system of conventional signs. The content of the map corresponds to the content of a map of a certain type and scale (All-Union State Standard (GOST) 28441-99) [7-9].
EMs are based on digital terrain models, that is, the data describing the objects and terrain characteristics. This data contains the spatial coordinates of objects, their type, attributes and set of attributive characteristics, expressed in numbers.

EM data characterize the course of the epizootic process. Adding this data to the attribute table allows to create digital nosological maps in GIS, when a thematic layer with epizootic information is displayed on EM. Synthesized digital noso-map can be visualized on a monitor screen, as well as stored in a graphical format or printed on paper [10-13].

In a new GIS-epizootological project the digital noso-map is a part of a whole set of layers with diverse geographical information. This allows to study epizootic data taking into account spatial relationships with geographical objects on a digital map. It also allows to analyse epizootical risk based on results of a comprehensive study of spatial and temporal patterns of data on the localization of cases of animal diseases and attributive data of the involved spatial (geographic) objects.

Risk analysis includes the process of hazard identification, risk assessment, risk management and risk communication. The process of hazard identification in an epizootical study is a process of determining the biological agent which is present in an animal and affects its health. GITs allow to connect all cases of identified biological danger with time and a spatial object on the EM. These data allow to make a mathematical model of a spatial and temporal position of the hazard and to perform risk assessment.

Risk assessment in the epizootical study is an estimation of chance of introduction or activation of a dangerous biological agent, modeling of the hazard spread as well as determination of biological and economic consequences. In GIS these procedures are performed using built-in or attached analysis modules of the computer application in use [14, 15].

Risk communication is a process of mutual exchange of information, opinions, protocols by experts during the risk analysis procedure, the subject of which is the risk itself, its factors and conclusions. GITs significantly accelerate and simplify the procedure of risk communication, which allows to prepare the exchange files of the required digital standard with high content.

GIS software for spatial and temporal analysis makes it possible to determine the territory boundaries of risk occurrence of natural focal zoo-antropozone infections as well as to define quantitative or qualitative indicators of the risk degree.

Analysis of dynamics of changes at the selected time period is made in GIS on the basis of the results of epizootical and/or epidemiological monitoring. Epizootical (and epidemiological) monitoring is the continuous implementation of appropriate measures and situation analysis, as well as routine surveillance to detect changes in a health status of the animal or human population. The monitoring results can be presented in a digital form and used to generate sets of dynamically changing noso-maps or maps showing the zones of occurred changes.

Natural focal zoo-antroponozine infections are diseases common to humans and animals, the etiologic agents of which can persist for a long time in the external environment in separate territories - natural epizootical foci.

A natural epizootical focus (NEF) is the territory where the etiologic agent of the infectious disease circulates among wild animals that live there permanently. Since there is a long probability period of aggravation of the epizootical situation which is associated with the spread of infectious animal disease in a given territory, NEF is a territory of a constant risk. The boundaries of NEF are formed on the basis of its territory belonging to a geographical landscape and climatic zone, favorable for a sustainable existence of the biogeocenosis in which the etiologic agent circulates.

The spatial distribution of registered natural foci of disease and predisposing natural factors in GIS can be used to perform analysis and assessment of a risk of new outbreaks.

The synthesized map layer of a natural focal risk can be overlaid in GIS on maps of settlements, zones of human economic activity and livestock facilities. In further analysis this overlay allows to assess the degree of epizootical and epidemiological risk.
Computer scenarios can be modeled where using of geo-informational technologies makes it possible to predict the development of the epizootical and epidemiological situation taking into account the options for carrying out anti-epizootical and anti-epidemic work.

GIT introduces a scientifically grounded approach in calculating the scales and volumes of necessary preventive measures, which significantly increases the effectiveness of anti-epizootical and anti-epidemic work with more rational use of material resources.

GISs can model and forecast epizootical and epidemic situation which allows to form correct bio-security plans that identify potential pathways for the introduction and spread of a disease in a zone or compartment and include a description of measures that have been taken or planned to reduce the risks associated with the infectious disease.

2. **Stages of epizootical analysis using geo-information technologies (GIT)**

2.1. **Creating a GIS project**

Various software platforms can be used to implement projects of epizootical geo-information system. These are:

- ArcGIS is a family of software products of the American company ESRI [www.esri.com], which allows to visualize (present in the form of a digital map) a large amount of geographically linked statistical information. These products can create and edit maps of all sizes: from the plans of land to the map of the world. ArcGIS also contains a wide range of tools to analyze spatial information.
- MapInfo [www.mapinfo.com] is a widespread system with extensive integration tools, which is mainly focused on the most accurate representation of maps and their use in determining the coordinates of points and routes. A wide range of options and popularity of this system allowed it to be ob a par with the world's leading GIS projects.
- QGIS [qgis.org] is a cross-platform open source geo-information system. All modules and analytical tools of this software are developed or completed by its users at no cost.

All the products listed above have the ability to use compatible unified file formats (such as shapefiles), which allows to aggregate design data from various GIS products.

Making a GIS project involves the following stages preliminary for building the information system (IS):

- Choosing the software to achieve desired goals.
  Examples of GIS software are presented above. The software is selected depending on a number of factors: required functionality and need for software development of standard modules, market value, user friendliness, presence of special software tools, ability to integrate with other IS, convenience of the end product, complexity of technical support solutions, etc.
- Creating a logical model of the future GIS.
  Links between attributes of the system, their status and ranges of domains are pre-established in the project under development. The same stage brings about considerations of possible using of a given basic spatial information (base maps), that is, the data layer on which our solution will be built in the future.
- Selecting modeling tools and criteria to construct data analysis models in GIS.
  The options of existing GIS-tools, as well as the need to develop new software modules and the complexity of this development are being assessed. There is a methodological selection of the criteria involved in coping with the assigned task. Their behavior and influence are determined depending on the given conditions. At this stage you also normalize quantitative values of the criteria, if necessary.

The next step brings about creation and filling a database for GIS.
2.2. Creating and filling the database for GIS with the help of database management system (DBMS)

According to the All-Union State Standard (GOST) 34.321-96 a database (DB) is a set of interrelated data organized to match a database plan in such a way that the user can work with them. All data in the database is structured into components (elements). Links between these elements allow the database plan to structure all data in order to enable their efficient search and processing in the computer system.

Computer database management systems (DBMS) are software platforms for creating and filling databases. They provide management of the procedure for collecting, storing and processing large data sets. Collaborative work with GIS-programs can be performed in MS Access. Advantages of this DBMS include a wide distribution, a simple and understandable interface, the ability to exchange with other common database formats. DBs containing objects related to a certain area of knowledge are considered thematic. DBs with epizoometrical data are referred to as epizootical databases. Designing a thematic database requires to take into account all possible characteristics of objects for subsequent analysis, by generating the corresponding fields in the table. The project draft consists of all possible formalized variants and values of objects of certain types in the database. The table field in the database can contain only a certain type of values. This ensure the possibility of subsequent analytical operations on the data, in order to minimize data errors and increase the reliability of information.

Design of a database requires to form links between tables according to a unique identifier key. The links between the tables are set according to the database plan. There is a tendency to use relational database plans on the principle of "what follows what" to establish such relationships: outbreak of disease - animal - farm unit - compartment - administrative district, etc. DBMS with a similar architecture is referred to as relational. The relational plan allows to link and process the data by belonging to the animal’s species, administrative area, date, etc.

Information on the recorded outbreak of natural focal disease is introduced into a relational database with reference to geographical coordinates or a populated locality (farm) where an animal or human infection has occurred. The database contains the date of detection of the disease, the number and age group of the diseased. If there is a disease of farm animals, the database includes information on the species composition of the diseased, the number of susceptible animals in the whole compartment where the outbreak has been recorded, information about the vaccination, and the number of people in contact.

Geo-coding. If there are no geo-referenced contamination zones to be included in the geo-database, geo-coding is performed. Geo-coding is a procedure that allows to relate (link) the objects under study to objects with known coordinates on the terrain (sources of binding). In our study, the sources of binding are markers of settlements, which location and spatial coordinates are defined in the data layer containing the original basic map information. Geo-coding is carried out in an automated mode using the address locator of the GIS application software, or in manual mode by inserting into the geo-information database coordinates of objects and semantic information on them, also linked to a marker of the settlement.

Developing epizootical GIS. This stage includes development and editing in the GIS software environment of electronic maps and a geo-information database. The geo-information database has the architecture of a relational database management system (DBMS), which allows to combine the attributive tables of used maps and tables with descriptions of epizootical objects.

Introducing a set of thematic layers. Cartographic layers of the landscape, soils, flora, hydrography are additionally introduced into the project of the epizootical GIS to analyze the characteristics of the biogeoecenosis, which provides the functioning of the natural focus of the disease. The project also contains the range of the animal population that are the reservoir of the disease, and the range of the animal population that carry the disease (in vector-borne diseases). Calculation of the necessary anti-epizootical and anti-epidemic measures demands the maps of the administrative division of territories, settlements, the transport network and the direction of transfer of animals to seasonal pastures, livestock facilities to be introduced into the GIS-project. Diseases, whose pathogen can persist in the soil, are marked on a dead animals’ burial map. The characteristics of the animal burial site - year of
burial, the number of biothermal pits, area (m²), belonging and status of the cattle graveyard - are indicated in the cartographic database.

Creating a layer of the risk map of natural focal diseases. A raster or vector layer is created by using analytical GIS tools. The layer reflects risk gradations in the investigated territories based on the results of stochastic (probabilistic) modeling of the epizootical process. Territory boundaries of epizootical risk are determined by spatial data of the detected epizootical foci, which are taken as indicator (reference) points. This data is used to perform a mapping interpolation of the possible location of other epizootical foci in the same territory by using geostatistical analysis tools. Calculation of qualitative risk criteria, with a gradation from low risk to increased risk, brings about epizootical and epidemiological zoning of territories in the GIS, which allows assessing the potential epizootical hazard of the objects in medium and long term period. Mathematical modeling of risk allows to take into account the risks of existence of natural foci of infection even in the absence of previously reported cases of the disease. It also allows to identify, on the basis of the calculation results, potentially dangerous territories and to give recommendations on necessary preventive measures to anticipate emergent (emerged or appeared suddenly) outbreaks.

Analysis of the spatial and temporal location of foci of infection. Based on results of comparison of the density of the cases detection for different time periods, a map reflecting changes in the border and intensity of the manifestation of the noso-areal is drawn up in the GIS application. This allows to give exact characteristics to the vector of spatial displacement of the infection for the selected period, to construct a short-term forecast of the epizootical situation dynamics and to determine the current boundaries of a threatened zone (the zone with the highest probability of detecting the disease in the real time period).

Mathematical modeling of the spread of natural focal infection among agricultural animals, taking into account the anti-epizootical work. Combined GIS maps of the risk of natural focal infections occurrence, of the number of susceptible animals and of plans of anti-epizootical measures allow to estimate the sizes of groups of epizootical risk and to construct a short-term forecast of the epizootical situation development. This modeling allows to choose in advance the optimal allocation of resources of the veterinary service for carrying out anti-epizootical measures.

Analysis of the effectiveness of anti-epizootical measures. A retrospective GIS analysis of epizootical situation in the territory of risk and of economic costs incurred to carry out anti-epizootical measures allows to assess the effectiveness of their application.

Making scientifically grounded epidemiological forecasts. Epidemiological risk maps are compiled taking into account the location of the territory of risk of zoo-anthropotical diseases occurrence, localization of human settlements and zones of human economic activity.

3. Conclusion
Geo-information technologies allow to conduct procedures for analysis and assessment of the risk of natural focal infections, including:

- assessment of the probability of biological and economic consequences of the spread;
- risk management;
- risk communication.

Using computer software for risk analysis and assessment allows to standardize this process and to provide the transparency (evidence) of the procedure, when all data, methods, results and conclusions are documented automatically. The conclusions follow from statistically significant mathematical calculations.

The architecture of the epizootological GIS can be extended to any number of noso-logical units (diseases), including those that are not part of the natural focal group. This makes it possible to use the epizootological GIS project as a risk management tool for all especially dangerous, transboundary,
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