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Mapping and Analysis of *Anthrax* Cases in Humans and Animals

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Abstract

Anthrax is a rare but severe disease caused by the gram-positive, rod-shaped bacterium Bacillus anthracis, a toxin-producing, encapsulated, facultative anaerobic organism. *Anthrax* occurs naturally in the soil and mainly affects livestock and wildlife. It can cause severe diseases in both humans and animals. *Anthrax*, an often-fatal animal disease, is spread to humans through contact with infected animals or their products. People become infected with *Anthrax* when the spores enter the body. The study aims to localise and monitor *Anthrax* on geographic maps and identify geographic variables significantly associated with environmental risk factors for *Anthrax* recurrence in Georgia (Caucasus), as the geographic environment affects specific diseases, for example, soil and climate, etc. We carefully analysed 1,664 cases in humans and 621 in animals, up to 1,430 locations of *Anthrax* foci in soil (animal burials, slaughterhouses, BP roads, construction, etc.). We analysed more than 30 geographic variables such as climate, topography, soil (soil type, chemical composition, acidity), landscape, etc. We have created several digital thematic maps and foci of *Anthrax* distribution and detection. The discovered variable will help to monitor the foci of *Anthrax* development.

Keywords: Anthrax, Geodata, Infection, Cartography, GIS Analysis

Introduction

Anthrax is a rare, acute bacterial disease that spreads to animals and humans. The bacterium is caused by Bacillus anthracis, which spreads as a spore in the soil and even remains there for several decades. *Anthrax* is especially common in herbivores. After grazing on large-grained grass, animals receive wounds in the gastrointestinal tract, allowing bacteria to be placed in the wound, damaging the host organism and causing death. There are three ways of spreading the disease: contagious, alimentary, and aspiration, the first of which is promoted by blood-sucking insects.

As it is clear from the records, *Anthrax* has existed in Georgia since ancient times, but different names have been given to this disease. However, the correct definition of *Anthrax* is described in the 1697 monograph of the Georgian writer, scientist, and public figure Sulkhan-Saba Orbeliani. He defines Anthrax as a devastating disease for animals and humans [1]. Even though anti-Anthrax actions are constantly taking place in the country, Anthrax still poses a significant threat to our country today.

Methods and Materials

We carefully analysed 1,664 cases of Anthrax in humans and 621 cases in animals, up to 1,430 locations in soil (animal burial grounds, slaughterhouses, BP roads, construction sites, etc.) recorded in Georgia. The data are taken from the National Centre for Disease Control and Public Health of Georgia, which scientists have researched for over 70 years [2, 3].

Originally, these data were handwritten, with many inaccuracies. The geographical coordinates are corrected, and the exact location of the settlements is indicated. Some cases went beyond the state borders of Georgia, so the accuracy of the manuscript coordinates was corrected.

Data was entered into the ArcGIS programme. We have compiled over a hundred thematic, complex, and analytical maps: relief, landscape, forest cover, soils, plants, protected areas, etc. Then, on all the compiled maps, the *Anthrax* detection coordinates were used to obtain the corresponding variables at the *Anthrax* detection sites: *Anthrax* distribution relief height, exposition, climate, soil types, soil acidity, structure, minimum and maximum air temperature, vegetation, landscape, and wind direction.

Distances were measured between settlements and *Anthrax* hotspots and between *Anthrax* hotspots and drinking and non-potable water. We also calculated the *Anthrax* intensity at each point (in some cases, it was 224 times for 70 years) to analyse which geographic variable determines the distribution and intensity of *Anthrax*.

We have compiled climate maps of Georgia, the central database of which is https://www.ecad.eu/download/ensembles/download.php: elements: daily mean temperature TG, daily

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minimum temperature TN, daily maximum temperature TX, daily precipitation sums RR, where the database is available in regular grids of 0.1 and 0.25 degrees. To create a map, we took multi-year diary data (1965–2010) and calculated the multi-year average. Because the data on this website can only be viewed at 45 degrees east longitude, we have completed climate maps with data from local meteorological stations. After data aggregation, the data grid was recreated via kriging.

Results

Geographical components have a positive effect on the spread of *Anthrax*. One of the main geographical components is the soil and climate.

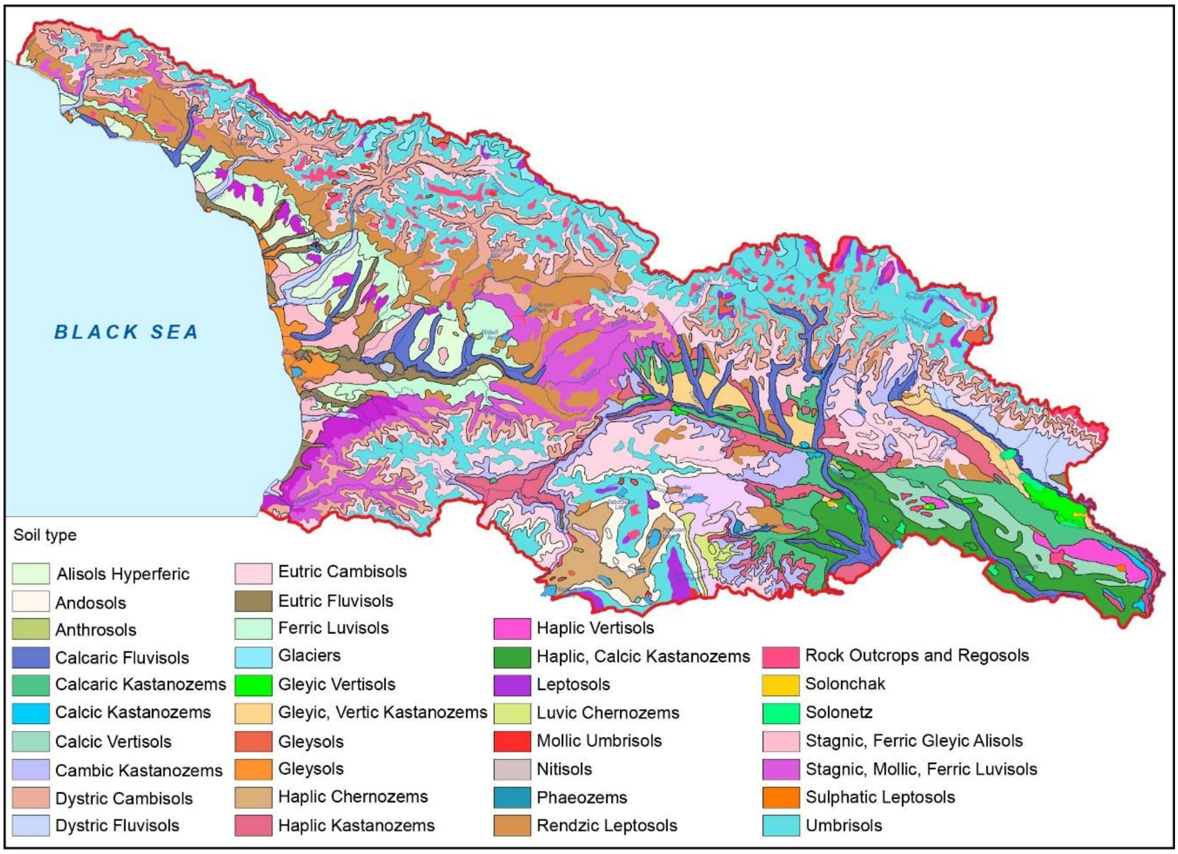

Figure 1. Soil type

Impact of Soil on Anthrax

The soil is a reservoir of *Anthrax* spores, as evidenced by numerous studies. The most favourable places for the *Anthrax* bacterium are black soil, brown soil, and alluvial soil, which the river brings and deposits. Humus also contributes to the spread of spores (4% or more than 4%). These are: red soils, humus-carbonate soils, ash soils, black soils, especially on arable lands, and mountain-meadow cord soils with the highest humus content. Is -8, 26–18, 81% [4].

Anthrax also contributes to the spread of soil moisture, a temperature regime of 15–45 degrees Celsius, and various chemicals and amino acids [5].

A soil map is crucial for studying *Anthrax* spread because it is crucial to analyse which soil type affects the *Anthrax* bacteria's storage, life, and distribution.

The map is compiled in the programme ArcGIS. The basis of the soil map is the National Atlas of Georgia soil maps [6], published in 2012 and 2018 (Figure 1). The soil types and characteristics of the recompiled map help us analyse *Anthrax's* distribution.

The digital map of soils has the following defined parameters: soil texture, soil organic matter content (%), soil pH, mean soil pH", average base saturation (mg/100gr soil), average calcium carbonate concentration (%), average calcium sulphate concentration, "soil salinity (EC in microelements/cm)", Fe in soil %, Cu in soil mg/kg, Mn in soil mg/kg, Zn in soil mg/kg, Al in soil (%), Ti in soil (%), Ni in soil (%), and Al Thirty-four types of soil in Georgia, where the data are given for soil type, humus, and structure of each type of soil, and databases are created for *Anthrax* variables and analysis (Figures 2 and 3 The digital map of soils has the following defined parameters: soil texture, soil organic matter content (%), soil pH, mean soil pH, average base saturation (mg/100 g of soil), average calcium carbonate concentration (%), average calcium sulphate concentration, soil salinity (EC in microelements/cm), Fe in soil %, Cu in soil mg/kg, Mn in soil mg/kg, Zn in soil mg/kg, Al in soil (%), Ti in soil (%), Ni in soil mg/kg. Thirty-four soil types in Georgia were given the data on the humus and structure of each type of soil and used to create databases for *Anthrax* variables and analysis (Figures 2, 3, and 4).

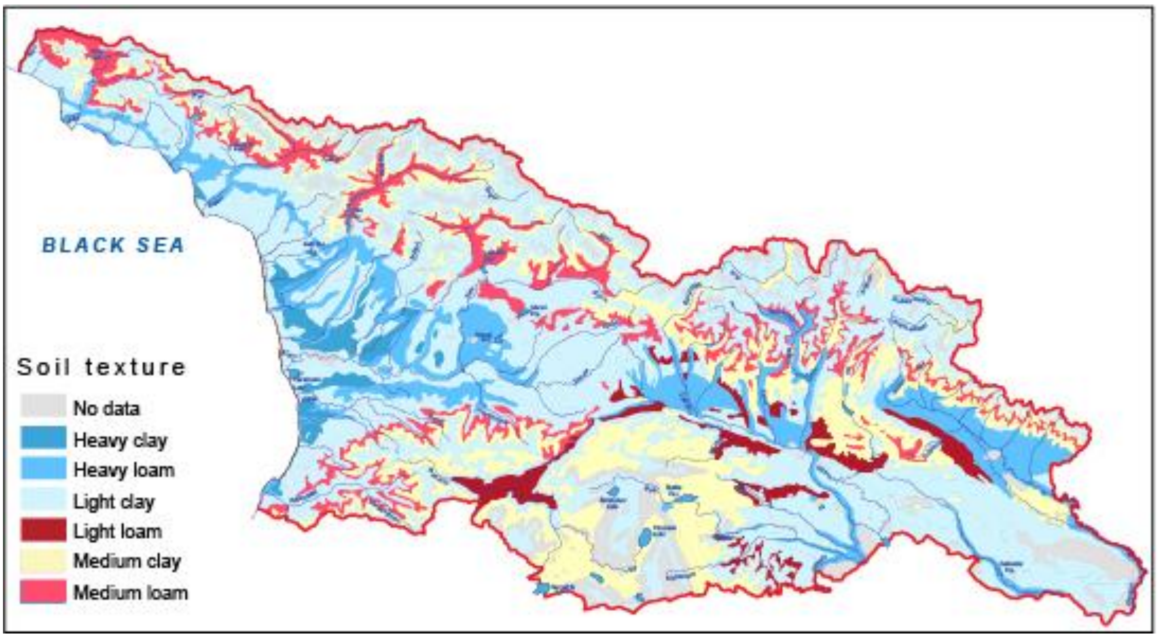

Figure 2. Soil texture

Analytical maps showed that *Anthrax* is found in all municipalities of Georgia, although the prevalence and intensity are very different. For example, the intensity of *Anthrax* is highest in Shida and Kvemo Kartli, followed by Kakheti, and Samtskhe-Javakheti. This is because livestock is mainly developed in these regions.

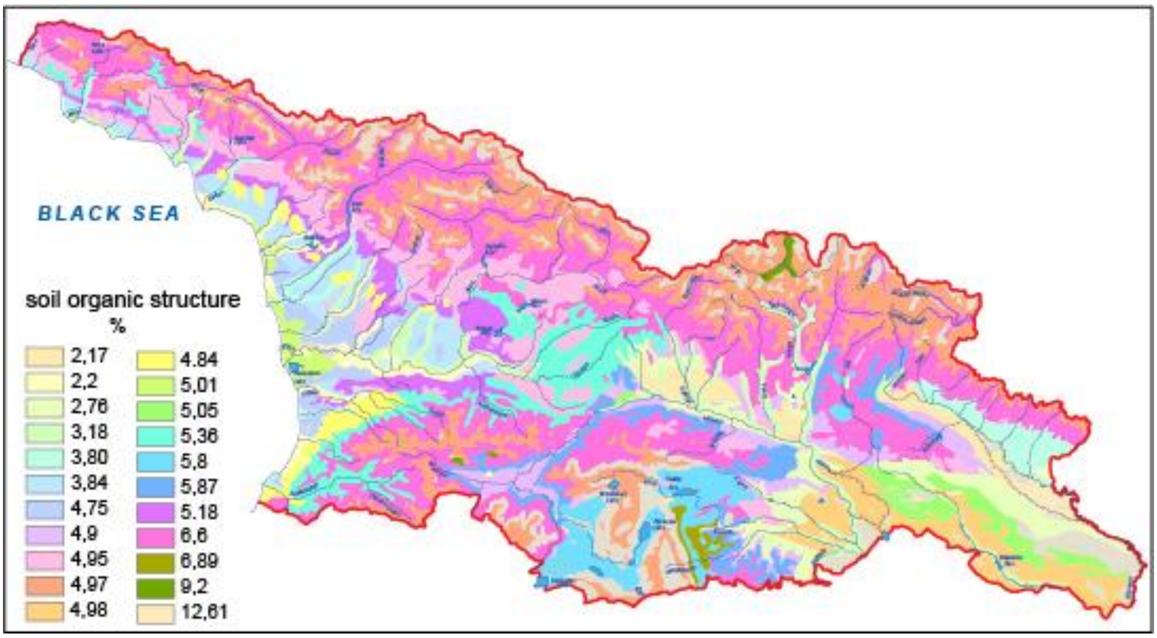

Figure 3. Soil organic matter content

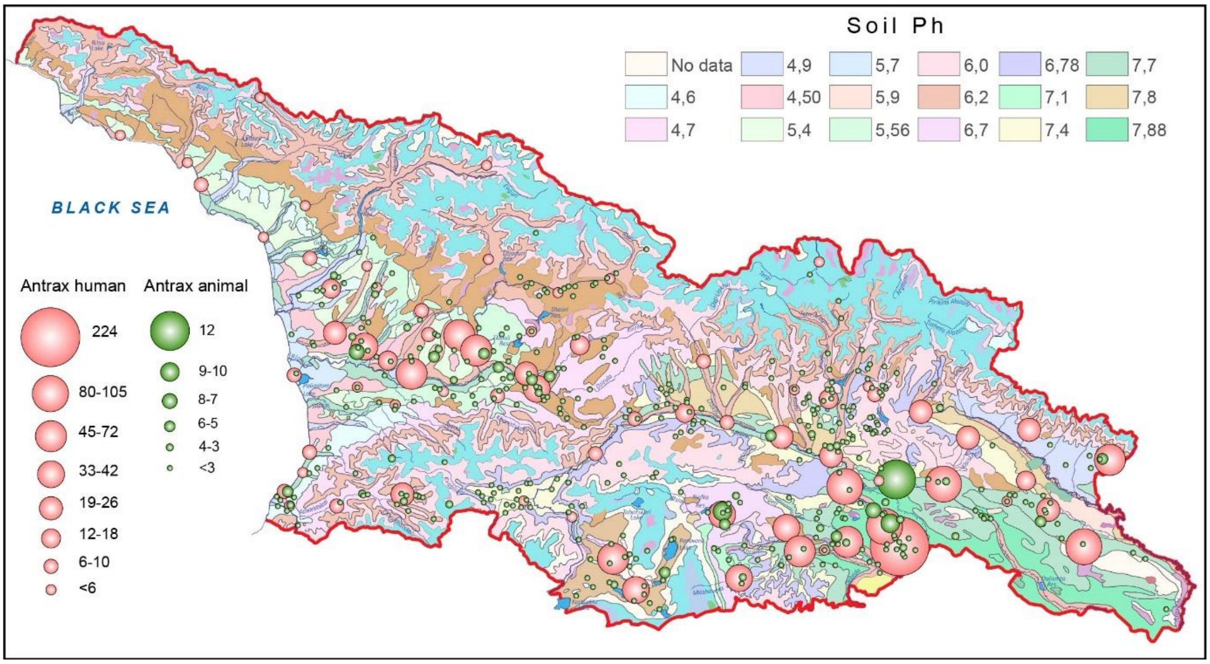

Figure 4. Anthrax density by soil Ph

Figure 5 Analytical maps showed that *Anthrax* is found in all municipalities of Georgia, although the prevalence and intensity are very different. For example, the intensity of *Anthrax* is highest in Shida and Kvemo Kartli, followed by Kakheti and Samtskhe-Javakheti. This is because livestock is mainly developed in these regions (Figure 5).

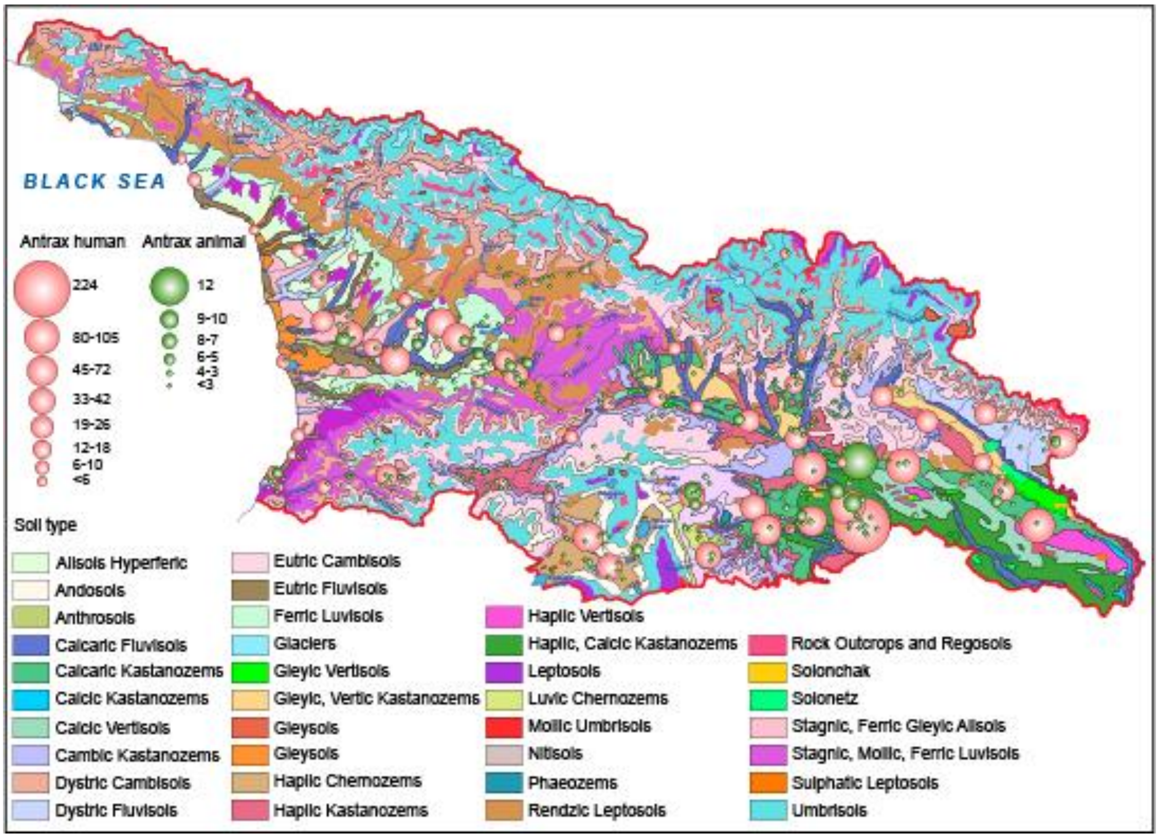

Figure 5. Intensity of Anthrax disease by the soil type

As the analytical maps showed, the main foci of *Anthrax* and high levels of intensity were mainly observed where the following types of soil had their characteristics: 1) Alluvial calcareous: Soil texture:

heavy loam; soil organic matter content: 3.18%; soil pH: 62; average base saturation: 20,89 mg; average calcium carbonate concentration: 2,9%; soil salinity (EC in microelements/cm): 115,4; Fe in soil: 7,66%; not found here - Cu, Mn, Zn, Ni, as for Al in the soil is 15,81%, Ti – 0.55. *Anthrax* 155 foci have been identified in the distribution area of this type of soil; 2) Cinnamonic: 60 centres of *Anthrax* have been identified in the distribution area of this type of soil. Soil characteristics are Soil texture: light loam; soil organic matter of the content of 4.9%; soil pH: 7.4; average base saturation: 23,07 mg; average calcium carbonate concentration: 7.5%; soil salinity (EC in microelements/cm): 87,0; Fe in soil: 7.99%; not found here - Cu, Mn, Zn, and Ni; as for Al in the soil, it is 17,07%; Ti is 0.57; and 3) Rendzic leptosols: 51 centres of *Anthrax* have been identified in the distribution area of this type of soil. Soil characteristics are Soil *texture*: light loam; soil organic matter content: 4,95%; soil pH: 7,8; average base saturation: 28,1 mg; average calcium carbonate concentration: 20,13%; "soil salinity (EC in microelements/cm) 68,8, Fe in soil is 12,72%; not found here: Cu, Mn, Zn, Ni; as for Al in the soil, it is 12,75%; and Ti is 0.68; an equal number of foci are found in yellow soils and alluvial acid soils, and then they are sequentially distributed: eutric cambisols, chernozems, yellow podzolic gley soils, andosols. The smallest *Anthrax* is recorded in red soils, dystric cambisols, mountain forest meadows, and claysols. *Anthrax* is not fixed in western Georgia, Eutric cambisols, or mountain meadows.

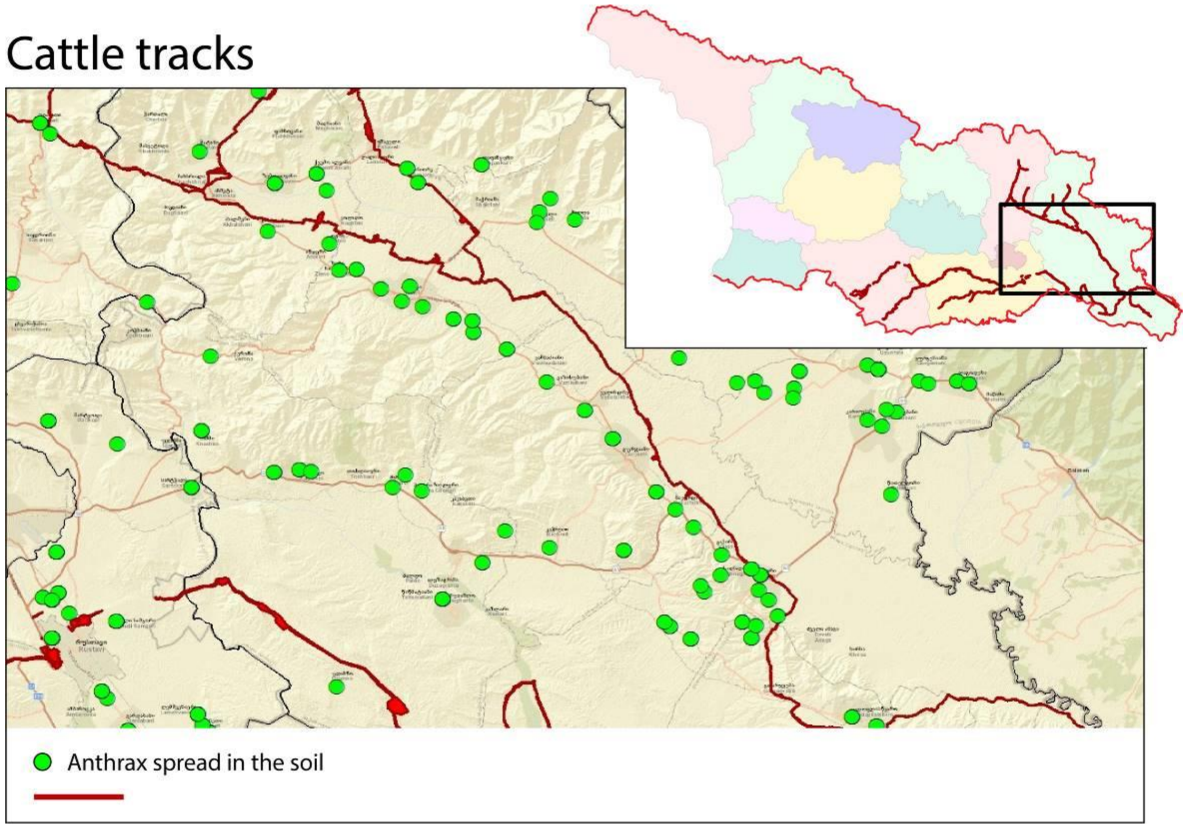

Figure 6. Cattle tracks, Small fragment, Kakheti region

The spread of *Anthrax* is facilitated by the movement of cattle on the roads. Seasonally, these trails operate from July to October. At this time, the surrounding areas, settlements, and populations are threatened as *Anthrax* bacilli are excreted in the urine, faeces, blood, and other biological fluids of infected animals. Animal-eating insects that feed on the carcasses of infected animals may also play the role of mechanical carriers in causing and spreading the disease. When exposed to free oxygen, environmental conditions affect the *Anthrax* bacillus, which produces dormant (non-plant) spores, is resistant to environmental conditions, and maintains infectivity and viability in soil, animal fur, water, and plants for decades. [6] Diseases from the soil are easily spread by rainwater and irrigation canals within a radius of several kilometres (Figure 6).

Influence of Climate on Anthrax

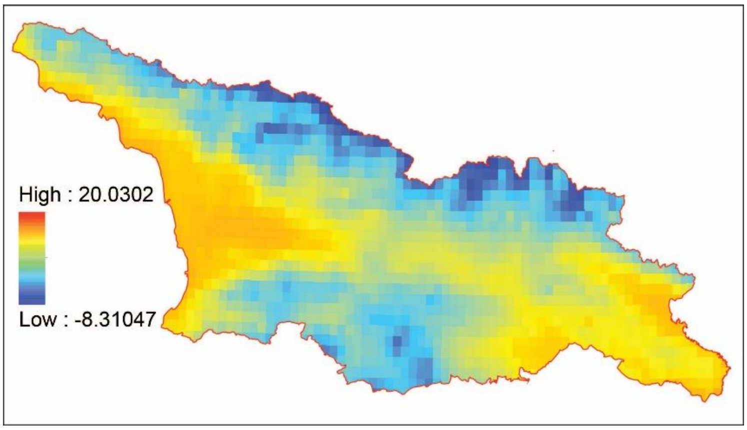

Figure 7. Elements daily mean temperature

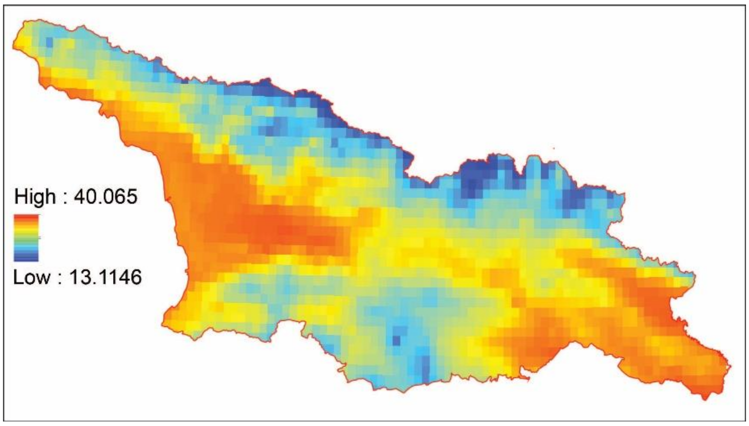

Figure 8. Daily maximum temperature

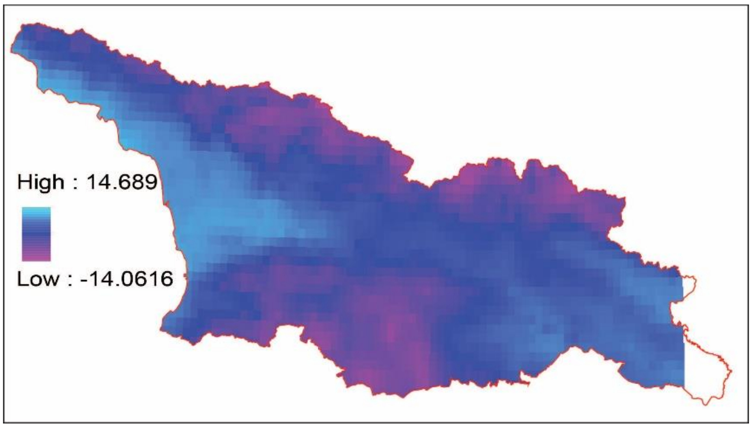

Figure 9. Daily minimum temperature

One of the main factors in the spread of infections is the geographical component—climate. Because of this, we have compiled climate maps of Georgia: elements daily mean temperature TG, daily minimum temperature TN, daily maximum temperature TX, and daily precipitation sum RR. Where the database is available in regular grids of 0.1 and 0.25 degrees, to create a map, we took multi-year diary data (1965–2010) and calculated the multi-year average. Because the data on this website can only be viewed at 45 degrees east longitude, we have completed climate maps with data from local meteorological stations. After data aggregation, the data grid was re-created via kriging: the average temperature of Georgia, the absolute maximum, the annual average (calculated from daily maximums), the annual average (calculated from daily minimums), and precipitation (multi-year average calculated from daily total) (Figures 7, 8, 9, and 10).

Georgia has a warm climate, which is favourable for the spread of *Anthrax* and high intensity. The higher the relief height, the lower the temperature, and the lower the *Anthrax* spread and intensity. In some places, for example, on the Greater Caucasus Range, the Caucasus watershed ridges, or the Lesser Caucasus, there are no manifestations of *Anthrax*.

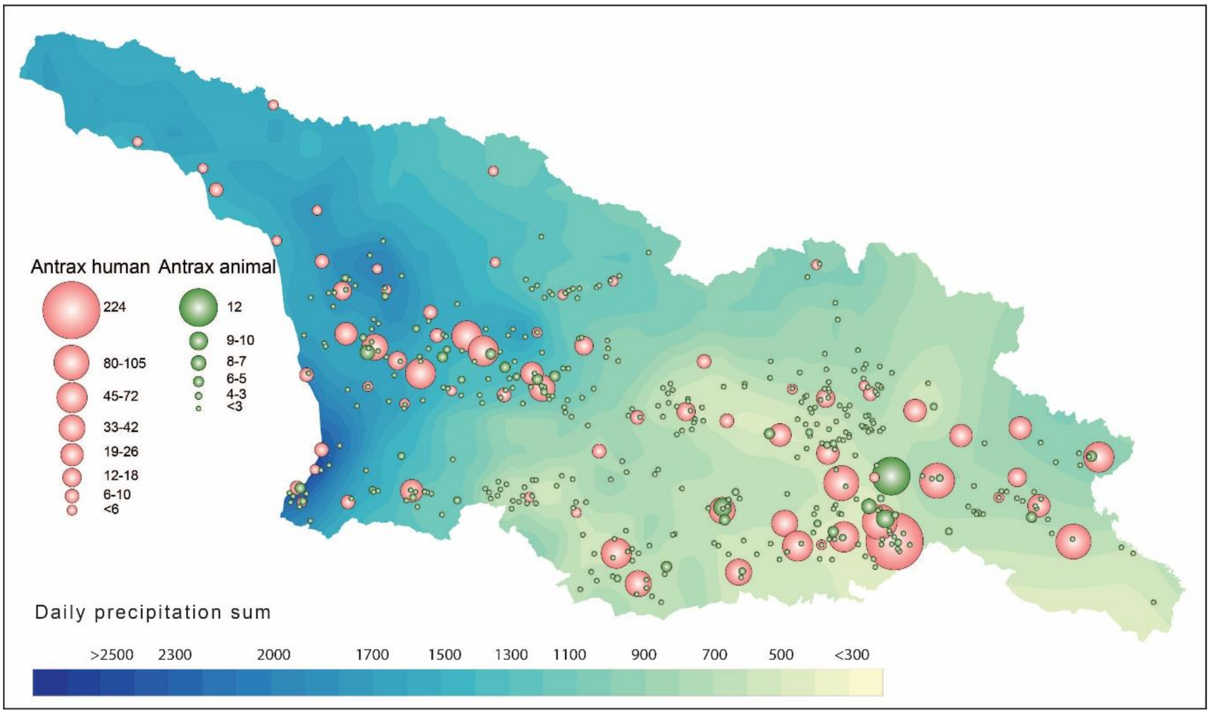

Figure 10. Intensity of Anthrax disease. Daily precipitation sum

Conclusion

- During high temperatures, the spread of *Anthrax* is intense in the plains. The risk of *Anthrax* spread decreases with increasing altitude. Irrigation with untreated water also contributes to the spread of *Anthrax*, in which the bacillus enters the upper layers of the soil and is transferred to pastures;
- The spread of *Anthrax* spores is also facilitated by the ways of transporting livestock, during which the animals spread the *Anthrax* bacilli or leave these bacteria in the soil for hundreds of years.
- Soil types and their chemical composition have been related to the preservation of the *Anthrax* bacillus for centuries.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

T.C. and L. M. conceived of the presented idea. T.C. and l. M. performed the analytic calculations. All authors provided critical feedback and helped shape the research, analysis and manuscript.

Acknowledgements

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