Geographical Information Systems in buffalo health applications

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ABSTRACT: Over the past 10-15 years, significant advances have been made in the development and application of geographical information systems (GIS) and remote sensing (RS). In veterinary sciences, particularly in veterinary parasitology, GIS and RS offer powerful means for disease mapping, ecological analysis and epidemiological surveillance and have become indispensable tools for processing, analysing and visualising spatial data. They can also significantly assist with the assessment of the distribution of health-relevant environmental factors via interpolation and modelling.

Key words: Geographical information systems, Remote sensing, Disease mapping, Veterinary parasitology.

INTRODUCTION - Disease mapping and environmental risk assessment using geographical information systems (GIS) and remote sensing (RS) technologies are now established as basic tools in the analysis of both human and veterinary health (for a review see Cringoli et al., 2005). However, epidemiologists have needed time to become convinced that the prospects offered by GIS and RS could be useful in their own discipline. The last 15-20 years have seen an ever increasing reliance on cartographic representation of infectious diseases, particularly parasitic infections and their vectors (Bergquist, 2006). In fact, during the past two decades the publication of original research articles and reviews in veterinary and human health with an emphasis on GIS and/or RS has followed an exponential trend (Hendrickx et al., 2004). In addition, recent GIS/RS symposia organized at national and international conferences and several thematic issues on this topic published in the peer-reviewed international literature (e.g. special theme issues in Advances in Parasitology in 2000 and 2006; Parassitologia in 2005) demonstrate the wide array of applications and benefits of these tools (Cringoli et al., 2005; Rinaldi et al., 2006). Furthermore, the publication of thematic books pertaining GIS and RS, as well as international peer-reviewed journals, including the current launch of Geospatial Health (www.geospatialhealth.unina.it) attest to the increased interest in these new technologies. The establishment and maintenance of websites as a platform for sharing data and exchanging opinions, experiences and expertise on GIS and RS, with an emphasis on animal and public health, is also worth mentioning (for example http://www.gnosisgis.org).
WHAT IS A GIS? - Depending upon the application area, a number of discordant definitions of GIS have appeared in the literature (Tim, 1995). One of the most widely used definition of GIS is that proposed by Burrough (1986), i.e. “a powerful set of tools for collecting, retrieving at will, transforming, and displaying spatial data from the real world”. Overall, a GIS is a platform consisting of hardware, software, data and people and encompasses a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analyzing, and presenting information that are geographically referenced (geo-referenced).

The use of GIS in epidemiology can aid in answering some important questions such as “what is?” and “where is?” In addition, because also the time domain - i.e. “when” - is important in most environmental and epidemiological processes, it has also been suggested that GIS should be replaced by STIS, which is an abbreviation for space-time information systems (Kistemann et al., 2002; Hendrickx et al., 2004). There is currently a movement towards regarding GIS as a science (geographical information science) rather than a simple technology (Goodchild, 2000; Kistemann et al., 2002).

DISEASE MAPPING - One of the most useful functions of GIS in epidemiology continues to be its utility in basic mapping. Usually, when data are collected either routinely or through purposely designed surveys, they are presented in tabular forms, which can be exploited for analytical usage. However, the reading and interpretation of such data is often a laborious and time-consuming task and does not permit easy decision making (Paolino et al., 2005). On the other hand, representation of these data in the form of a map facilitates interpretation, synthesis and recognition of frequency and clusters of phenomena. Today, GIS, RS and Global Positioning Systems (GPS) are well known tools of the trade and few scientists working in the fields mentioned can manage without them. As we enter the era of Global Earth Observation Systems (GEOS), the old adage that a picture is worth more than a 1000 words rings truer than ever (Bergquist, 2006).

Disease maps can be drawn to a demographic base or to a geographic base. In the first case, they are related to the population and the epidemiological information they show are presented in relation to population size. Geographically based maps are constructed according to the shape of a country or a region or any administrative unit. They may be qualitative e.g. point maps, distribution maps, point distribution maps (PDMs), indicating location without specifying the amount of disease; or quantitative e.g. distribution maps with proportioned peaks, proportional circle maps, choroplethic maps, choroplethic maps with proportioned peaks, PDMs with proportioned peaks, PDMs with proportioned circles, isoplethic maps, displaying the number of cases of disease, the population at risk, infection prevalence or intensity or incidence (Thrusfield, 1995; Cringoli et al., 2005; Rinaldi et al., 2006). With the appropriate data at hand, producing a map using GIS can be undertaken literally in a matter of minutes; but therein lies one of the problems with GIS - one needs the spatially explicit data - and collecting these may take months or even years (Durr, 2004). GIS is, however, not only a digital map representation but is indeed an information and analysing tool which permits the processing of space-related data. Certainly, maps themselves keep on playing a prominent role and are, of course, the most frequently used output of GIS (Kistemann et al., 2002). For spatial epidemiology, GIS has become an important tool for designing a study, territorial sampling, and the drawing of maps. The fundamental steps which can be used to produce quality descriptive
disease maps within GIS are the following: (i) selection of the study area; (ii) selection of the study population and calculation of the sample size, using as parameters the study population, the expected prevalence, the confidence level, and the standard error; (iii) selection of the sample in the study area (e.g. random sampling, systematic sampling, proportional allocation, use of grids, etc.); (iv) laboratory and/or field survey; (v) geo-referencing of the study units (e.g. farms, counties, municipalities, regions, or any other administrative unit); and finally (vi) drawing maps by GIS (Cringoli et al., 2005; Rinaldi et al., 2006).

The sampling procedures in the study area play obviously a key role in disease mapping. As indicated at point 3 above, several sampling methods can be used. For parasites of water buffaloes in the Italian farm management system, the grid approach (measured on the sample size) followed by proportional allocation seems to be useful in order to produce usable disease maps without need for further interpolation or extrapolation.

This approach has been recently used by us in order to study the presence and distribution of parasites (protozoa, helminths and arthropoda) in water buffalo farms from the Latium region of central Italy. A grid representing quadrants of 5 x 5 km was overlaid on the study area within the GIS. As a result, the study area was divided in equal quadrants, and the buffalo farms that formed the sample were chosen to be proportionally allocated at quadrant level, i.e. the number of farms sampled in each quadrant was proportional to the total number of study population in that quadrant (Fig.1). Within these numerical constraints, the specific farm(s) to be studied in each quadrant were randomly selected among all the farms geo-referenced into the GIS database.

Figure 1. Example of grid sampling followed by proportional allocation.
ECOLOGICAL ANALYSIS - Ecological analysis is targeted on the description of relations existing between the geographic distribution of diseases and environmental risk factors and their analysis by means of statistical procedures (Kistemann et al., 2002). A wide number of papers have been published on the analysis of the relationship between disease indicators (e.g. positivity, incidence and prevalence) and the explanatory environmental and climatic variables (Herbreteau et al., 2005). In order to make ecological analysis, the following fundamental steps can be utilized: (i) GIS construction for the study area utilizing data layers on environmental and climatic features; (ii) geo-referencing the geographic units of interest, e.g. farms, centroids of the main pastures, etc.; (iii) creation of buffer zones of a given diameter centered on these geo-referenced points; (iv) extrapolation of values for each environmental feature within each buffer zone; (v) databases with environmental and parasitological data; (vi) statistical analyses (univariate, multivariate, etc.) and individualize of environmental risk factors and/or development of forecast models (Cringoli et al., 2005; Rinaldi et al., 2006). Few studies are present in literature on ecological analysis of diseases of water buffaloes. For example, a GIS model for mapping the risk of fasciolosis in buffaloes was developed and validated for the Kingdom of Cambodia using determinants of inundation, proximity to rivers, land use, slope, elevation, and the density of cattle and buffaloes (Tum et al., 2004, 2007); and a GIS analysis on transmission of schistosomiasis in water buffaloes was developed in China (Zhou et al., 2000).

EPIDEMIOLOGICAL SURVEILLANCE IN VETERINARY MEDICINE - In veterinary epidemiology, the advantage of mapping the locations of farms and other facilities with animals is obvious. In an outbreak of a disease it could make the management of the situation easier, and it could also provide a tool to evaluate different strategies to prevent the spread of diseases. Scientists working towards optimisation of nation-wide disease control require data on the epidemiological key issues “who, what, where, when, why and how”, provided through integrated, hierarchical (ecological data, data on farm, herd and animal level) information systems. Linked with GIS, the spatial structure of animal populations and the characteristics of disease transmission (within herd, between herds through animal movement) can be dealt with using powerful descriptive and analytical tools. Within the activities of the project “MAPZOO” recently funded by the Campania region of southern Italy, a GIS has been constructed utilizing as datalayers the topographic base map (at the scale 1: 25,000; source: Italian Geographic Military Institute - IGM) and Digital aerial photographs (at 1.0 meter resolution, comprimed in ECW format; source Cartographic Office of the Campania region) of the Campania region. Based on this GIS, all the buffalo (Fig. 2), cattle, sheep and goat farms present on the whole territory of the Campania region of southern Italy have been geo-referenced on digital aerial photographs. It should be noted that geo-referenced data by the traditional use of GPS is expensive and less precise than alternative techniques based on aerial photographs (Cringoli et al., 2006). The availability of the precise locations of farms is very useful for further studies (i.e., spatial analysis) and for the control and eradication of livestock diseases, in particular those infecting water buffaloes.
CONCLUSIONS - The trends over the past two decades and their effects in the fields of hardware, software and network technology, in particular in the internet domain, have created the prerequisites for a broad acceptance of GIS and RS within the health sciences, including veterinary science.

Epidemiology remains the main application field of GIS in veterinary and public health and, since epidemiology is inextricably bound to “place”, it seems reasonable to expect that GIS will further advance as science (Jacquez, 2000). Perhaps one of the most powerful benefits of GIS is its ability to integrate different databases into a single environment. In effect, a GIS may be thought of as a database of databases (Cox and Gifford, 1997). In conclusion, with the appropriate data at hand, GIS can be very useful to study the epidemiological patterns of infections in veterinary health, in particular regarding water buffaloes.

REFERENCES – Bergquist, R., 2006. Preface. Geospatial Health, 1: 1. Burrough, P.A., 1986. Principles of Geographical Information Systems for Land Resources Assessment. Clarendon, Oxford. Cox, A.B., Gifford, F., 1997. An overview to Geographic Information Systems. JAL, 11: 449-461. Cringoli, G., 2006. Mappe Parassitologiche 7. MAPZOO,
Cringoli, G., Rinaldi, L., Veneziano, V., Musella, V., 2005. Disease mapping and risk assessment in veterinary parasitology: some case studies. Parassitologia, 47: 9-25. Durr, P., 2004. Spatial epidemiology and animal disease: introduction and overview. In: Durr P and Gatrell A, editors. GIS and Spatial Analysis in Veterinary Science. CABI Publishing, 35-67. Goodchild, M.F., 2000. Communicating geographic information in a digital age. Ann Assoc Am Geogr, 90: 344-355. Hendrickx, G., Biesemans, J., de Deken, R., 2004. The use of GIS in veterinary parasitology. In: Durr P and Gatrell A, editors. GIS and Spatial Analysis in Veterinary Science. CABI Publishing, 145-176. Herbreteau, V., Salem, G., Souris, M., Hugot, J.P., Gonzalez, J.P., 2005. Sizing up human health through remote sensing: uses and misuses. Parassitologia, 47: 63-79. Jacquez, G., 2000. Spatial analysis in epidemiology: Nascent science or a failure of GIS? J Geog Sys, 2: 91-97. Kistemann, T., Dangendorf, F., Schweikart, J., 2002. New perspectives on the use of Geographical Information Systems (GIS) in environmental health sciences. Int J Hyg Environ Health, 205: 169-181. Paolino, L., Sebillo, M., Cringoli, G., 2005. Geographical information systems and on-line GIServices for health data sharing and management. Parassitologia, 47: 171-175. Rinaldi, L., Musella, V., Biggeri, A., Cringoli, G., 2006. New insights into the application of geographical information systems and remote sensing in veterinary parasitology. Geospatial Health, 1: 33-47. Thrusfield, M., 1995. Veterinary Epidemiology. Blackwell, London, UK. Tim, U.S., 1995. The application of GIS in environmental health sciences: opportunities and limitations. Environ Res, 71: 75-88. Tum, S., Puotinen, M.L., Copeman, D.B., 2004. A geographic information systems model for mapping risk of fasciolosis in cattle and buffaloes in Cambodia. Vet Parasitol, 122: 141-149. Tum, S., Puotinen, M.L., Skerratt, L.F., Chan, B., Sothoeun, S., 2007. Validation of a geographic information system model for mapping the risk of fasciolosis in cattle and buffaloes in Cambodia. Vet Parasitol, 143: 364-367. Zhou, X., Sun, L., Jiang, Q., Guo, J., Wang, T., Lin, D., Yang, G., Hong, Q., Huang, T., Zhang, S., Wang, Q., Hu, F., Guo, J., 2000. Geographic information systems spatial analysis on transmission of schistosomiasis in China. Zhonghua Liu Xing Bing Xue Za Zhi, 21: 261-263.