SCHISTOSOMIASIS: GEOSPATIAL SURVEILLANCE AND RESPONSE SYSTEMS IN SOUTHEAST ASIA

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ABSTRACT

Geographic information system (GIS) and remote sensing (RS) from Earth-observing satellites offer opportunities for rapid assessment of areas endemic for vector-borne diseases including estimates of populations at risk and guidance to intervention strategies. This presentation deals with GIS and RS applications for the control of schistosomiasis in China and the Philippines. It includes large-scale risk mapping including identification of suitable habitats for *Oncomelania hupensis*, the intermediate host snail of *Schistosoma japonicum*. Predictions of infection risk are discussed with reference to ecological transformations and the potential impact of climate change and the potential for long-term temperature increases in the North as well as the impact on rivers, lakes and water resource developments. Potential integration of geospatial mapping and modeling in schistosomiasis surveillance and response systems in Asia within Global Earth Observation System of Systems (GEOSS) guidelines in the health societal benefit area is discussed.

1.1 Introduction

Geographic information systems (GIS) and remote sensing (RS) from Earth-observing satellites offer high-resolution spatio-temporal datasets for rapid assessment of areas endemic for vector-borne diseases, including estimates of populations at risk and guidance to intervention strategies. This paper focuses on schistosomiasis, which is of particular interest from this point of view as all the factors (water bodies humidity, temperature, etc.) that limit the geographical distribution of the snail intermediate host of this parasitic disease can be downloaded from many various satellites. Not only are these factors directly useful, but the prevailing temperatures give also an indication of how fast the parasite stage inside the snail grows. In addition, a too high or a too low temperature of the snail may kill the parasite before the snail succumbs.

Schistosomiasis has been the subject of control approaches for the better part of the last century and is continuing. These activities have met with varying degrees of success, while progress has seldom been possible to sustain for long due to continued transmission and waning complacency of populations being treated. This is the situation in The Philippines, while China has made continued progress from the start of the national control programme in the early 1950s (Bergquist and Tanner, 2010). According to recent studies the prevalence in The Philippines is highly erratic; between 1% and 50% depending on the area investigated (Olveda, 2014). The geography varies considerably in contrast to China, where the endemic areas are predominantly found on the great plains. A major difference is that China has endemic seasons due to its more northern situation, while transmission goes on throughout the year in The Philippines.

Thus, The Philippines represents a challenge to control activities, while China has been able to bring the number of infected people down from around 11-12 million, at peak prevalence according to Chen (1999), to currently less than 300,000 and has now embarked on a strategy to eliminate the disease as a public health problem. This means that they are at a point where mass drug administration (MDA) can be replaced by surveillance and response, a situation focusing on geospatial screening, sensitive diagnostics and immediate response directed at transmission hotspots (Bergquist et al., 2015). However, this straightforward approach is challenged by rising population and the potential for a future warmer climate. More people, elevated temperatures and higher mobility will unquestionably lead to augmented maturation of infectious agents and escalating numbers of vectors/ intermediate hosts putting transmission into high gear with vastly enhanced risks for human infection as result. Thus, the need to sustain what has been achieved becomes increasingly important.

Effective surveillance systems make it possible to localize areas at risk, or the most affected population groups, identifying infections in the definitive host that require intervention and assessment of the situation (Bergquist et al., 2015). The purpose is discovery, investigation, and elimination of continuing transmission, including prevention and cure of infection. Timely dissemination of surveillance results improves implementation and evaluation of ongoing public health activities (Lukwago, 2012). The shift of focus from morbidity and mortality to transmission signifies the important move from the general control stage to that of elimination. There is a strong need to concentrate on rapid detection of existing, new or re-introduced infections. To serve its purpose, a surveillance-and-response system needs to be based on the concept of the minimal, essential data approach taking the potential for drug resistance into account. The scientific challenge lies in the creation and validation of (i) the minimal, essential data set required, and (ii) the minimal, effective sampling frame in time and space. These basic requirements not only entail making the best use of mapping and modelling approaches by assisting the definition of the minimal essential sets with respect to data and sampling approaches, but also contribute to better forecasting capabilities and development of improved diagnostic tools.

This review focuses on implementing a geospatial health infrastructure for control of schistosomiasis and other helminthic infections in Southeast Asia, with special focus on the People's Republic of China and The Philippines, using a model working group approach. Health workers have lagged in utilization of geospatial analysis and widely available, low-cost spatial data resources for epidemiological modelling and control programme management. The critical limitation on development of useful health applications to date has not been the availability of geospatial data and methods. Rather, the key barriers have been the speed of adoption of geospatial analysis tools by health scientists and the quality of GIS friendly medical databases.

2.1 Regional Geospatial Health Capability

Regional GIS applications on Asian schistosomiasis were reviewed in 2010 (Malone, 2010) to illustrate recent geospatial health analysis applications. A model programme was presented for implementation of training programmes and establishment of regional working groups to facilitate development and use of geospatial health infrastructure resources by health workers in Southeast Asia. Establishing a geospatial health capability typically involves a three-step process—compilation of GIS layers of archival spatial data relevant to health applications, development of data layers on health surveillance systems and creation of control programme decision support systems (Brooker, 2006).

3.1 Minimum medical GIS databases

Public domain satellite imagery data (e.g. Landsat, MODIS and SRTM) and point, line or polygon feature (vector) data on the environment (e.g. climate, hydrology, ecological zone and soil), administrative/political boundaries (e.g. Africa Data Dissemination Service), infrastructure (e.g. roads and railroads) and populated places that will be useful for nearly any health GIS project may be archived as an open data resource and then supplemented with additional data depending on the application and the biology of the disease agent, for example, environmentally sensitive vector-borne agents versus agents spread by contact.

4.1 Health data

It is becoming routine practice to geolocate health infrastructure facilities (e.g. rural clinics, hospitals and service area) and survey/study sites in Asia and Africa in the field, and to map available surveillance data using handheld global positioning systems (GPS) units. Medical workers often have additional access to decades of excellent published field and laboratory studies, but much data in the early literature are imprecisely located by geographic coordinates, and often must be looked up by name or other identifiers of study site in gazetteer databases such as the NIMA GEOnet Names Server (www.nima.mil) before it can be useful in a GIS spatial decision support system for a given disease agent. More recently, virtual globe technologies, Google Earth^{TM} and Google Maps^{TM} in particular, have come into use for capturing point and polygon coordinates of health data records and for visualizing, exploring and disseminating health data (Stensgaard, 2009).

5.1 Decision support systems

Commercial and public domain spatial analysis software and spatial statistics packages, such as WinBUGS (London, UK) for Bayesian statistics, SaTScanTM (New York, NY) for time–space data analysis, Neural Solutions (Gainesville, FL) for neural networks analysis, the Genetic Algorithm for Rule-set Prediction and Maximum Entropy (MaxEnt) (Phillips et al., 2004) based statistics are coming into wide use for development of disease risk prediction models. Using these programmes, it is possible to develop probability maps of disease risk using only limited case records and environmental databases so that researchers can define the spatial distribution of diseases by extrapolation to areas where quality health data does not yet exist; results are based on the ecological features found at points of known distribution and abundance.

Decision support systems must then be developed based on the biologic preferences and limits of tolerance of specific disease systems within a given environmental/ecological context. Environmental satellite imagery data and feature data resources are currently available for use in a GIS at spatial resolutions appropriate for studies ranging from continental/regional scale (e.g. 1 km^2, MODIS), agricultural field scale (e.g. 15–30 m^2, Landsat ETM+) or habitat scale analysis (e.g. 0.6–4 m^2, QuickBird). A closer collaboration between groups such as RNAS+, the International Society for Geospatial Health (GnosisGIS) and the Global Spatial Data Infrastructure Association (www.gisd.org) can play a central role in promoting the routine use of geospatial models in health decision-making processes. A joint platform would not only serve the regional control programme but also be instrumental in establishing geospatial health training programmes and trans-boundary working groups for regional health scientists, for example, groups interested in the neglected tropical diseases (Hurlimann, 2011). An increasing number of studies on Asian schistosomiasis and other zoonotic helminths are being developed and initiated with emphasis on GIS, RS and GPS applications and geospatial analysis approaches. A spatial database on multiparasitic infections, including geostatistics (spatial point pattern analysis and cluster analysis), has been proposed for Southeast Asia (Steinmann, 2010). New work has been published on use of GIS to forecast the potential expansion of endemic schistosomiasis zones effects associated with impending climate change (Zhou, 2010). Even more promising: The advent of sub-meter resolution satellite data (eg. Worldview 3) and sensitive and specific diagnostics have opened the possibility of modeling disease at the household-habitat level within local communities at risk

6.1 GeoHealth: An Open-source Digital Resource for Mapping and Modeling the Ecology of Disease

Despite these advances that demonstrate the value of geospatial mapping and modeling for health applications in individual studies, often at national scales, little progress has been made to develop and implement a multidisciplinary regional and global approach to utilize the full potential of geospatial health methodologies. Comprehensive geospatial health applications have been limited by the narrow scope of individual institutions or small organizations with limited personnel and geospatial analysis resources focused on a single or limited number or disease entities. There is a need for effort at a larger national and international agency scale that enable partnering of health scientists and earth scientists in creating a larger geospatial health enterprise.

Recent development of open-access, spatially explicit databases such as the Malaria Map Project (www.map.ox.ac.uk/) and the Global Neglected Tropical Disease Database (www.gntd.org) offer unique opportunities for disease risk modeling, targeting control interventions, disease surveillance and geostatistical analyses of disease distribution in space and time. Next steps will require operational, dynamic linkages and access by the health community to rich comprehensive digital geographic databases and advanced global models on environmental determinants of disease generated by geographers and environmental scientists, eg. NASA earth observing satellites and global climate models. We describe here *GeoHealth*, a new initiative by the International Society for Geospatial Health-GnosisGIS, to develop open-source, interoperable digital resources for mapping and modeling the distribution and abundance of diseases of public health importance. *GeoHealth* will seek to join with the Intergovernmental Group on Earth Observations (GEO) comprised of 100 Member states, and 92 Participating Organizations. GEO's primary focus is to develop a Global Earth Observation System of Systems (GEOSS) to enhance the ability of end-users to discover and access earth observation data and convert it to useable and useful information. Under the public health societal benefit area, *GeoHealth* will improve the flow of appropriate environmental data and health statistics to the health community. The success of GEOSS is dependent on interoperability based on non-proprietary international standards, including technical specifications for collecting, processing, storing, and disseminating shared data, metadata, and advanced products needed to graduate from morbidity control to surveillance and response systems that enable the new focus on disease elimination.

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