Potential, Limits and Rational Use of Remote Sensing and Spatial Analysis in Epidemiology

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Summary

During the last forty years, remote sensing has been increasingly used in epidemiology following the development of earth environmental satellites. Their raising number and better resolutions offered new opportunities to locate and understand the fundamentals of transmissible diseases to humans. However, a review of their applications shows a global limitation in the range of investigations, use of sensors and processes in epidemiology, altogether revealing discrepancy between theoretical and practical uses. Cost of satellite images remains the major constraint leading to the acquisition of free images or remotely sensed ecological variables from Internet, but with little relevance to the subject. Access to pertinent data and strengthening exchanges between epidemiologists and geographers will ensure a future of remote sensing in epidemiology.

Introduction

Remote sensing (RS), referring to the technique allowing the study of objects without any direct contact, through image capture (Hay, 2000), has been dedicated to Earth observation for more than forty years, since the launch of TIROS-1 (Television Infrared Observation Satellite) in...
1960, a US meteorological satellite, and also Landsat I in 1972, the first satellite designed specifically to monitor the Earth’s surface. Since the first images and ecological analyses, epidemiologists have been using RS tools, looking for ecological indicators of the presence of different pathogens, hosts or vectors. Remotely sensed data provide as various information as the nature and structure of land cover (eventually the land use with high resolutions), hydrological network, human settlements, and climatic variables: surface temperatures, cold-cloud duration as an estimate of rainfall, or even soil moisture (Beck et al., 2000). Increase of the satellite image and aerial picture offer coming with an improvement in the four resolutions (spatial, temporal, spectral and radiometric) of remotely sensed images have provided great possibilities for understanding the ecology of pathogens, vectors and monitoring diseases in near-real time (Huh and Malone, 2001). Despite recurrent praises of these techniques described as the future main source of data in epidemiology and regular publications of articles making use of RS with no relevance to the health issue, we decided to exhaustively review the literature to assess what has been the real use and benefit of RS in epidemiology and understand what are the limitations to pertinent implementations.

Materials and Methods

We started by reviewing the literature through the medical search engine Pubmed® (www.pubmed.com) and general search engines (yahoo®.com and google®.com) using keywords associated to RS and epidemiology (i.e. remote sensing, satellite, epidemiology). Then we performed similar searches in the journals or publishers websites. We also picked-up more references in each of the selected papers. We grouped together the different papers referring to a unique research study: same health investigation, study area, material and methods used. We especially investigated in each paper the data and analysis performed.

Results

187 articles were found dealing with RS and human health, either 119 research papers using RS as tools of investigation or 68 general reviews of the techniques. Among these 119 articles, we isolated and analyzed 86 articles corresponding to different researches, and published between 1976 and 2004 in 48 different journals, 1 book and 2 proceedings of conferences. Most of the articles tackle parasitic diseases (59% of the studies), including schistosomiasis (16.3%), malaria (16.3%) and, trypanosomiasis (10.5%). Viral diseases represent only 12% of the studies, with only one on Dengue Fever, while West-Nile Fever, Nipah Encephalitis, Avian Influenza have surprisingly not been
investigated using RS tools. Bacterial diseases are also poorly represented (9%) with six researches on Lyme disease, one on plague, one on cholera and none on other zoonosis directly associated to the environment (i.e. leptospirosis and melioidosis), for which remotely sensed data should be precious indicators. Twelve studies assess the vector presence, either mosquitoes or ticks, independently of the pathogens carried. Two studies focus on pathogens, their prevalence correlated to remotely sensed meteorological and environmental variables.

Regarding the diversity of satellites and sensors available, a few have been used in human Health studies: 43 analyzed NOAA-AVHRR, 35 Landsat MSS or TM, 8 SPOT-XS (20 meters) and 1 SPOT–Vegetation (1 km), 8 aerial pictures, 6 Meteosat, 2 SAR, 2 IRS-1A-1B - LISS-III, 1 TOPEX-Poseidon (radar altimeter) and 1 ER-2 – TMS (Thematic Mapper Simulator, onboard NASA’s ER-2 aircraft, with a 28-meter ground resolution). Landsat images are mostly acquired to classify whether land use or land cover and delimit vector habitats. None of the high resolution satellites (<10 meters) have been used for human health researches while they have been unanimously promoted of highest relevance in epidemiology. NOAA images are indirectly analyzed by users who acquire remotely sensed ecological variables, i.e. NDVI (Normalized Difference Vegetation), SST (Sea Surface Temperature), LST (Land Surface Temperature).

49% of studies use the NDVI calculation, generally acquired as an already processed index. Whereas over 13 vegetation indices have been developed to better describe specific environments, only two studies performed other indices both calculated with Landsat TM images, the Transformed NDVI (TNDVI) and the Perpendicular Vegetation Index (PVI). 27% of the studies performed temperature calculations (LST; diurnal Temperature Difference, dT; SST), and demonstrated a useful association between thermal differences and hydrologic environmental conditions inducing vectors abundance. Altogether there are only 42% of the studies which do not use any remotely sensed ecological variables.

Conclusions

RS provides a spatio-temporal ecological overview through environmental and climatic variables of the observed area that helps to determine environmental risk factors and predict health risk areas. Several studies offer a simplistic approach of diseases, calculating correlations between a single remotely sensed ecological variable (especially NDVI or climatic variables) and the incidence of diseases, which is contrary to the understanding of the complexity of diseases dynamics.

The main bias of most of studies is the acquisition of not always appropriated remotely sensed data, directed by the high cost of high-
resolution images and the availability of free datasets from websites. Then data are not chosen for their relevance to the study when spatial resolution should correspond to the specific scales and needs of the issue, showing the frequency of spatial variation in the observed area. Researches extrapolating a classification of the land cover often use a single image in regard to the cost and time-consuming processes, and, in some cases, it does not even cover the extent of the study area.

Studies based on epidemiological data should first investigate their significance, by assessing the heterogeneity and spatial structure of health outcomes in an explanatory manner. Epidemiological data are usually not representative of the real incidence of diseases, providing an observed incidence, image of the Health services structure, access and utilization. Endemic areas can be correlated to a larger number of cases, or better coverage of health services or presence of clinicians specialized in diagnosing the disease. Then a comparison of the distribution of cases with the distribution of service areas will show these biases. Epidemiological data recorded during several years present also some biases, the methods of diagnosis evolving with the time, especially for emerging diseases, remaining unknown to the doctors at the beginning of the epidemic.

Finally, considering the subjectivity of classifications and the hypotheses considered to derive environmental variables from images, fieldwork is a requisite step to construct and validate RS analysis. Ecological knowledge of pathogens and vectors, as well as epidemiological investigation, are necessary to carefully integrate RS data into models. Effective collaboration between geographers and epidemiologists will be a key to a better use of RS high potentialities in approaching diseases complexity.

References