GIS enabled spatial analysis of environmental pollution impacts on human health

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Environmental scientists and physical geographers have long been studying the distributions and spatial patterns of air and water pollutions. Although the general scientific understandings are that air and water pollution creates diseases and impacts the health of people, very few quantitative and spatially analyzed researches published in demonstrating the impacts or causes. The significant challenges exist between the focuses of medical and biological sciences and the scientific approaches of environmental and geographic information analysis. In particular, the former mainly focuses on understanding the disease factors in micro scale and to develop methodologies of reversing or preventing diseases. By contrast, the main objective and concern of the latter approach are on a regional scale and usually involving a large area or many people. This research attempts to visualize the possible impacts of the air and water pollution to human health in the specific geographic regions. Two practical examples are presented.

Figure 1. Air Pollution in Beijing, China

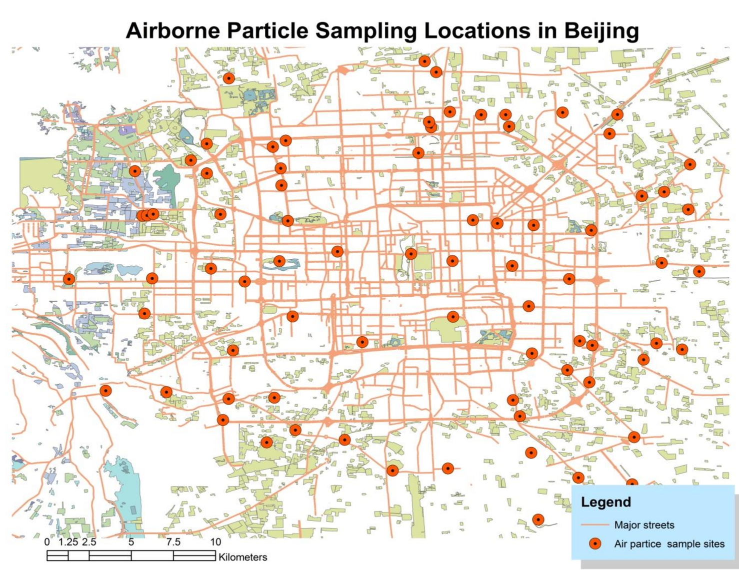

Figure 2. PM Air Pollution Sampling sites in Beijing, China

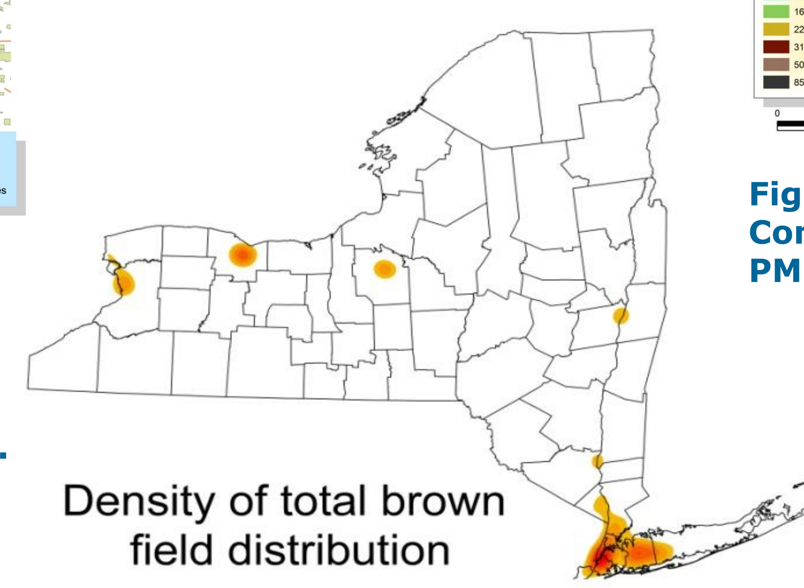

Figure 4.

Methods and Approaches

The first study was conducted in Beijing, China to analyze the spatial and temporal distributions of air particulate pollution and its impact to respiratory diseases (Figure 1). The concentrations of airborne solid particulate matter were monitored in the summer seasons during the year of 2007 to 2009 at 78 field sites in the urban districts of Beijing (Figure 2). Occurrences and treatment data of respiratory disease during the year of 2008 was collected from a medical record database in the City of Beijing. In discussion with local medical doctors and health experts, twenty different respiratory diseases were selected as indicators of the level of significance of the impacts. Some examples of these are upper respiratory tract infection, asthma, acute bronchitis, aspiration pneumonia, and allergic rhinitis.

Universal kriging (UK) model in geographic information systems (GIS) was used to spatially interpolate the point based air pollution survey data (Figure 3). Incidents of respiratory diseases in 2008 were geo-coded in GIS according to the home addresses of patients. The geo-coded data were then aggregated to the community level. The occurrences of respiratory diseases were normalized by the community population distribution data as the unit of cases per 100 people. Geographically weighted spatial regressions (GWR) were conducted in GIS environment for each of the five air pollution particulate sizes and the occurrences of respiratory diseases (Brunsdon et al., 1996).

The second study was conducted in the New York State, US for spatially analyzing the pollution impact of old industrial sites (brown fields) on colon and lung cancer incidents. The data of the old industrial sites was obtained from the New York State Department of Environmental Conservation (NYDEC). In this case, the industrial sites were abandoned. Either the environmental remediation work was accomplished, or the remediation is going on under the guidance of US Environmental Protection Agency (EPA). A total of 1026 records were geo-coded in GIS across the New York State.The sites were classified into four categories according the name of the company and its descriptions of the industry. These are chemical processing (CHEM), mechanical manufacturing (MECH), oil and natural gas exploration and storage (OILG), and waste material deposition (WASTE). The data of colon and lung cancer incidents in the year of 2008 was acquired from the New York State Department of Health (NYDOH). The incident data was statistically summarized from the treatment records of field hospitals, and aggregated by postal regions. The original tabular data was joined to the postal code geographic regions in GIS, and was normalized by population census of 2000. Kernel density analysis was applied to understand the spatial clusters of the old industrial sites by their categories(Figure 4). Geographically Weighted Regression (GWR) was applied to compute the degrees of impact of the old industrial sites on the cancer incidents.

Results and Discussions

In the first study, geo-coding and visualization of community respiratory diseases indicate that the highest occurrence rate in 2008 was 11 persons per 100 people of residential population, and it took place in the central west part of the city (Figure 5). GWR of PM0.5µM, PM1.0µM, and PM3.0µM demonstrated the positive coefficients. The average values are 5.23, 81.81, and 0.03, and the highest CN numbers are 10.01, 5.64, and 7.22 respectively (Figure 6). The results suggest that PM size from 0.5µM to 3.0µM impose a strong impact on the occurrences of respiratory diseases in the region. This result coincides with previous researches that lead the US-EPA's (Environmental Protection Agency) recognition of 2.5µM as the critical size in causing the human health problems and concerns (EPA, 2004). By contrast, both PM5.0µM and PM0.3µM show negative coefficients with high occurrence rates of respiratory diseases (Figure 7).

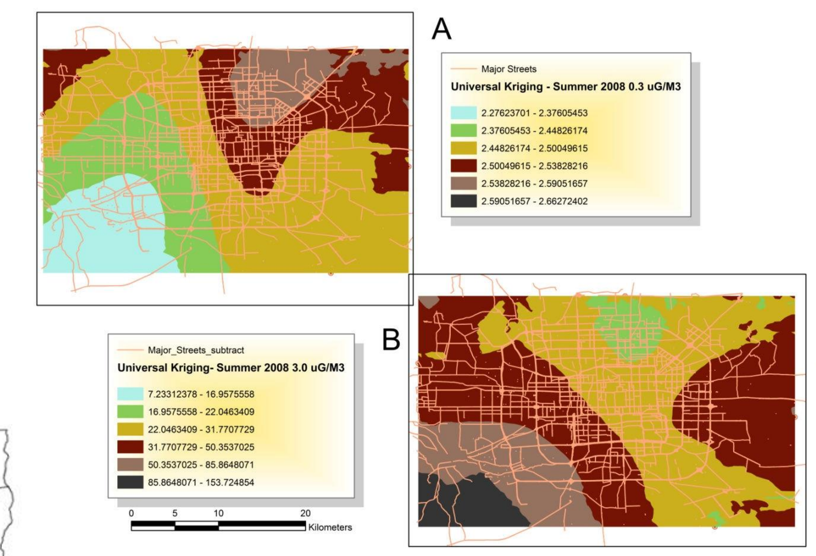

Figure 3. UK Modeled Concentrations of PM 0.3 µm and PM 3.0 µm in the summer 2008

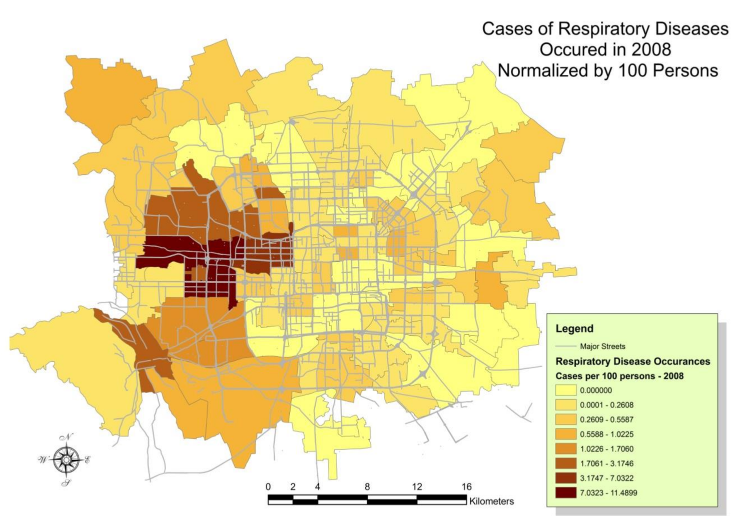

Figure 5. Occurrence Rate of Respiratory Diseases in Beijing - 2008

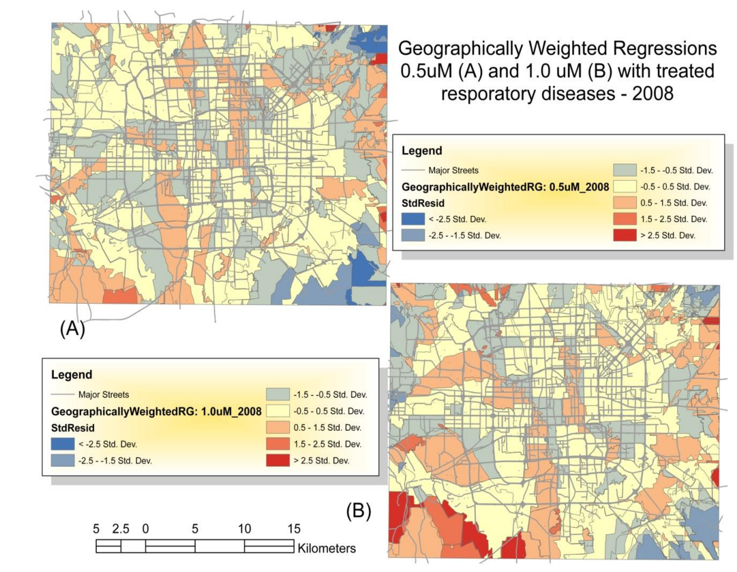

Figure 6. GWR residual map of PM 0.5 and 1.0 µM concentration and cases of respiratory disease in Beijing, 2008

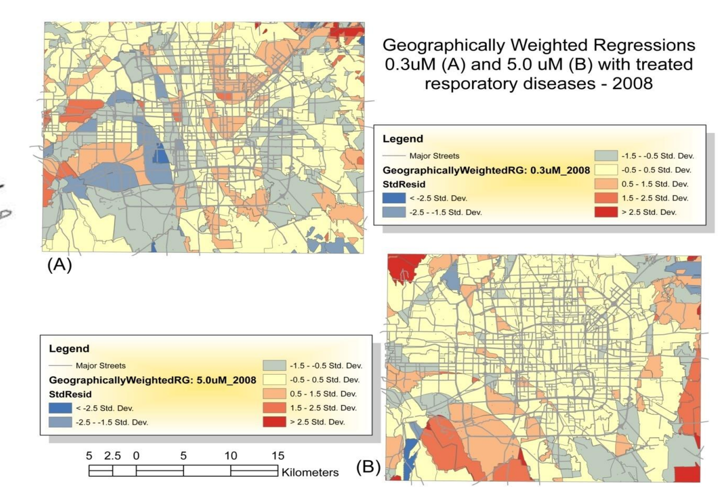

Figure 7. GWR residual map of PM 0.3 and 5.0 µM concentration and cases of respiratory disease in Beijing, 2008

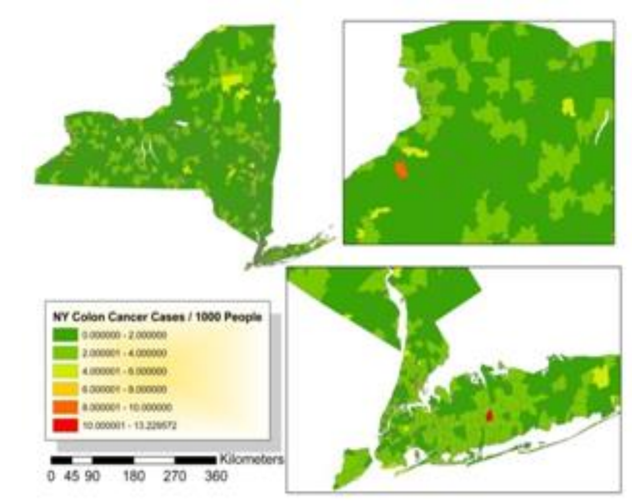

Figure 8. Total cases of colon cancer in 2008 normalized by population

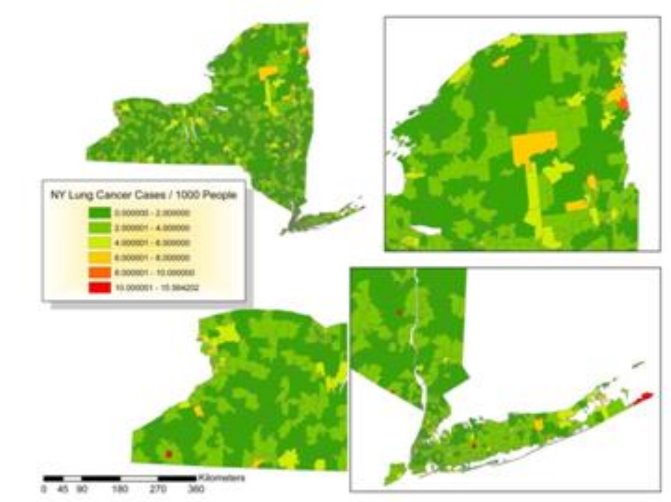

Figure 9. Total cases of lung cancer in 2008 normalized by population

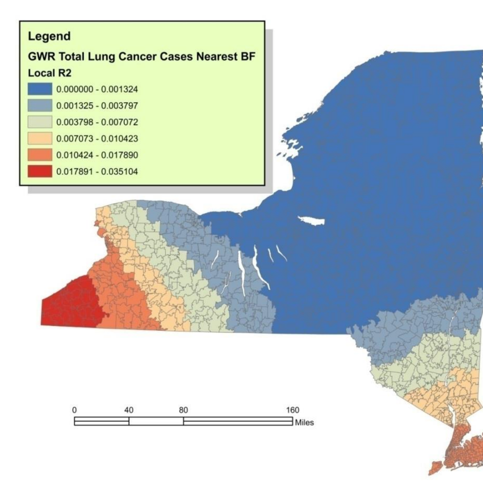

Figure 10. GWR - Local R^2 of Old Industrial Site Impact on Lung Cancer Incidents

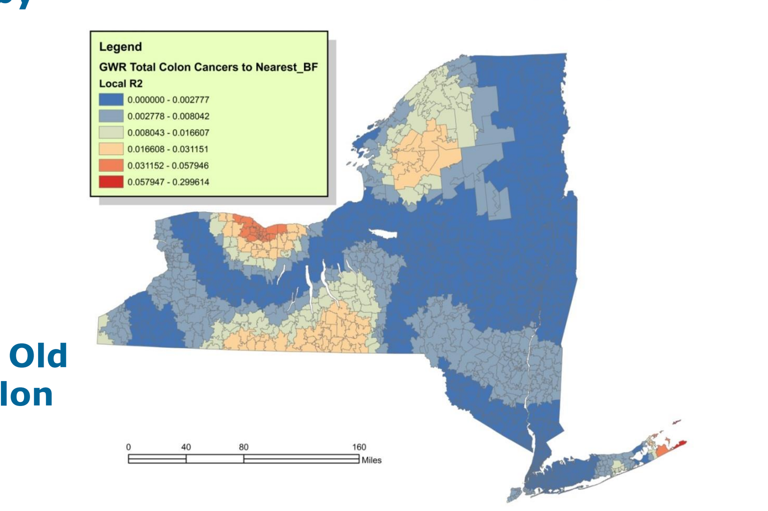

Figure 11. GWR - Local R^2 of Old Industrial Site Impact on Colon Cancer Incidents

The results of second study show that the high incidents of colon cancer per 1000 persons occur sporadically in the Long Island area, the Allegany Plateau of the Western New York, and the Adirondacks mountain region (Figure 8). The highest incident is 13 cases per 1000 persons in average. The high incidents of lung cancer per 1000 persons occur sporadically in the Long Island region, western low reach area of the Hudson River, the Adirondacks Mountain region, Erie, Niagara, and Cattaraugus counties of Western New York (Figure 9). The highest incidents per 1000 total population are 15.

The GWR modeling results show that a strong local relation exists between old industrial sites and high and moderate lung cancer incidents. The local R2 ranges from 0.16 to 0.75. (Figure 10). The spatial pattern of GWR prediction in some degree coincides with that of the lung cancer incidents. By contrast, colon cancer incidents do not show direct spatial relationship with old industrial sites (Figure 11). In summary, the GIS enabled environmental pollution factor analysis is an effective method for quantitatively assessing the impacts of human living environment on human health issues. Such kind of approaches may help the physicians in medical field to control or mitigate diseases at regional levels.

References

[1] Brunsdon, C. F., Fotheringham A. S., and Charlton, M. E. 1996. Geographically Weighted Regression: A Method for Exploring Spatial Non-stationarity. Geographical Analysis 28: 281-298

[2] EPA. 2004. Air Quality Criteria for Particulate Matter: Volume I. U.S. EPA publication: EPA/600/P-99/002aF