EMPOWERING PUBLIC HEALTH RESEARCH & OUTREACH WITH GEOSPATIAL TECHNOLOGY: CASES FROM THREE CONTINENTS

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Abstract— Increasingly provision and research into public health is being empowered by application of geospatial technologies (GST). These technologies include geographic information systems (GIS), global positioning systems (GPS) and remote sensing. In this paper the authors examine three case studies of application of GST to public health in three different contexts in three different countries located on three different continents. The continents are Africa, Asia and North America and the respective countries are Ghana, Malaysia and the United States of America. The applications of GSTs are to common endemic diseases in those countries. The issues are Ghanaian malaria, Malaysian dengue fever and in breast cancer in the USA. In each case GIS was used to store, analyze and generate maps of the prevalence of these diseases in relation to spatially distributed physiographic, cultural and demographic factors. The data are used for research as well as in the case of the USA for public outreach via web maps.

Keywords— Geospatial Technologies, Public Health, Ghana, Malaysia, USA, Malaria, Dengue Fever, Breast Cancer.

I. INTRODUCTION

Geospatial technologies are finding important applications in research and in improving outreach in the context of public health. In this paper the authors present three distinct case studies of such applications. The first case study is largely research oriented but nevertheless has practical applications to reducing the risk of malaria in the West African nation of Ghana. The second case study involves Malaysia and the study of the occurrence and environmental conditions that are associated with dengue fever in this Asian nation. The third case study involves mapping the spatial distribution of breast cancer in relationto cultural features, demographics and facilities designed to diagnose and treat this illness in the United States of America. Thus the three case studies all deal with three different diseases on three different continents. But they also have important differences that help to illuminate the wide diversity of applications of geospatial technologies. Geographically, they involve more than three far-flung countries on different continents. One nation is a developing one (Ghana) another is a rapidly developing technologically advanced nation (Malaysia) and the third is a highly developed nation (the USA). The case studies involve application of a diverse range of technologies including GIS, GPS, use of remotely sensed imagery and use of web-based interactive mapping over the Internet. Despite this diversity, these three cases are unified by the centrality of GIS in each instance as an integrating and analytical mapping technology.

II. SPATIO-TEMPORAL AND ENVIRONMENTAL MODELING OF MALARIA IN GHANA.

Malaria epidemics continue to be a major cause of morbidity and mortality across the world, with an estimated 1.2 billion at high risk (>1 in 1000 chance of getting malaria in a year). Overall, there were an estimated 198 million cases of malaria globally in 2013 and 90% of all malaria deaths occur in sub-Saharan Africa, and 78% occur in children under five. Children and pregnant women are severely and disproportionately affected by malaria in high malaria burden countries(1). Research has shown that the risk of malaria prevalence varies widely according to geographic region, year, and season (2)&(3). Also malaria prevalence shows significant variations in space and time (4).

Conflicting results exist on the roles of climate variability, physical environments, demography, and socio-economic status impacts on malaria prevalence. Adu-Prah and Tetteh (5), recently studied climate variability impacts on malaria prevalence using local and regional data from Ghana, West Africa. They used trajectory and time series analyses for temporal distribution and conducted GIS-based analyses of the spatial distribution of yearly malaria incidence and climate variables. They observed that the national annual malaria incidence has increased. There was also considerable inter-annual variations in the intensity of incidence across regions characterized with varying rainfall and temperature regimes. Their results indicated that temperature and humidity have a significant association with malaria prevalence in Ghana.

The use of GIS based spatial and temporal analysis in the study re-affirmed that although annual rainfall in the model was found to be less significant than some other population related factors, there is evidence of rainfall as a predictor of malaria in Ghana and other parts of the world. This may be a result of stagnant waterbodies in certain locations resulting from heavy rainfall providing breading grounds for the vector: the *Anopheles* mosquito. This could be an incubating

grounds for high risk transmission. In their study they recommended public health stakeholders to focus on areas with the highest malaria risk in Ghana when allocating resources. In particular, public health outreach, use of bed nets and spraying and draining stagnant water bodies.

Current research is ongoing to 1) identify at risk population of malaria using historical data, 2) examine key risk factors for malaria prevalence, and 3) develop an geographic information system based Malaria Early Warning Systems (GIS-MEWS) using the internet and web-based interactive maps to locally disseminate information and to provide a monitoring and evaluation mechanism for the country.

III. MAPPING AND SPATIAL ANALYSIS OF DENGUE FEVER IN MALAYSIA.

Dengue Fever is a viral mosquito borne illness spread by the *Aedes Aegypti* mosquito and generally found in equatorial and tropical countries (6). The disease is characterizedby high fevers and severe pains and afflicted 400 million people worldwide and is a leading cause of morbidity and mortality in developing countries including in Asia, Africa and the Caribbean basin. While it is generally not fatal in healthy individuals, it is debilitating and fatal in unhealthy individuals or those with inadequate health care. It is often found in areas where other illnesses like malaria, yellow fever and West Nile virus that are also spread by mosquitos are present. However many areas which have succeeded in eliminating yellow fever and reducing malaria have seen growth in dengue fever. The public health response to dengue fever includes identifying cases and establishing environmental factors that predispose an area to dengue fever prevalence. Also responses include supportive therapy for victims. The minimization of dengue fever depends of several approaches. These include draining stagnant water where mosquitos thrive, spraying aerial pesticides to combat swarms of mosquitos and (as with malaria) use of insecticidal bed nets. Since dengue fever is a tropical disease many of the places afflicted with it have other more serious health challenges and have not really targeted the disease as a priority.

However, in contrast Malaysia (while an intensely tropical peninsula with an even more equatorial area of Sarawak on the Island of Borneo) is a wealthy modern country with a penchantfor using geospatial technologies in advance of many developed countries in Europe for example.

ThusMalaysia and in particular the better mapped states of Selangor and Kuala Lumpur were a good place for researchers from Putra University, Surang, Malaysia the use of technologies like GPS to map not only towns or hospitals where dengue fever cases are recorded but also to identify the homes where victims were most likely infected. When these precisely determined locations were combined with data on the environmental and cultural factors in a multi-layer cadastral GIS several results were apparent. Specifically, dengue is most closely associated with rural areas where the population is of necessity outdoors working in fields, fishing and other activities where it is difficult to avoid contact with mosquitoes. Analysis of environmental factors indicates that proximity to water bodies particularly mangrove swamps and other areas that *Aedes Aegypti* favors and an important epidemiological factor (7).

The results of this spatial GIS based analysis of data gathered using GPS and analyzed along with classified remotely sensed imagery of environmental physiographic features such as mangrove swamps, gives public health practitioners important insights. In particular they can better staff local clinics, conduct education efforts, target eradication and consider the effectiveness of personal protection strategies such as use of insect repellants, bed nets and other relevantstrategies.

IV. WEB-MAP ASSISTED BREAST CANCER OUTREACH AND RESEARCH IN THE USA.

Breast cancer is a major health issue in developed countries. It is the leading cancer with over 240,000 new cases in 2015 and the second leading cause of cancer deaths with an estimated 41,000 in the USA in 2015 (lung cancer is second in cases 1st in deaths). While overall cancer is the second leading cause of death (after heart disease) in the USA (8). Women in middle age are most susceptible so the number of years of life lost isrelatively higher than for heart disease and stroke which strike women much later in life. Breast cancer is more commonly found in obese women and more prevalent and much more fatal in economically disadvantaged women and minorities in particular in African American women who tend to be disproportionatelypresent in all three categories(9). Efforts to detect breast early before it has had a chance to metastasize to adjacent lymphnodes and other organs offers the best current hope of improving rates of remission and five year survival rates. This early detection is usually accomplished through use of mammograms and breast examinations. Annual exams and (for older women and at risk populations) mammograms are a part of standard public health recommendations throughout the USA.

However, screening rates vary widely. In particular, the USA has many uninsured people and a decentralized, changing, costly and often chaotic system of health delivery. Only women who are motivated to take charge of their own health and willing to navigate delays, barriers and make a costly commitment of time and money are certain to get high quality medical screenings for breast cancer. Wealthy patients have the wherewithal to do this, many working people are covered by health insurance plans and/or enrolled in health maintenance organizations (HMOS) that facilitate this process but

for poor and particularly rural poor women this is more of a challenge. While the Affordable Care Act covers annual breast cancer screenings. The Act itself has only somewhat reduced the rate of uninsured while simultaneously making it harder for breast cancer suffers to access the best available treatment options due to many insurance plans restricting access to clinical trials and clinical research centers. Ironically, the very poorest women that are living in urban areas and are on public assistance may get more proactive screening done on their behalf by public health authorities targeting them with outreach efforts. Some of these outreach efforts use mobile screening vehicles that are taken to areas with clusters of underserved potential cancer victims such as public and subsidized housing areas. These vans use GPS and mobile maps to locate and navigate to target areas.

These outreach efforts are being greatly facilitated by use of GIS to record locations of breast cancer mortality and morbidity, to determine areas where services are available, to analyze demographics of areas where breast cancer may be most prevalent and to target outreach efforts including areas to send mobile vans and places to target resources on community clinics and screening programs. In addition interactive web-based mapping is used to disseminate information to the community about where screening and treatment services are available (10).

CONCLUSION

Geospatial technologies are powerful tools for public health practitioners and researchers. They are also increasingly valuable to disseminate information about public health threats and available resources to counter diseases to the general public. On a world-wide basis there are variations but many similarities in particular the use of GIS as a core technology is apparent.

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