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Original Research

Analysing malaria incidence at the small area level for developing a spatial decision support system: A case study in Kalaburagi, Karnataka, India

S. Shekhar[a], E-H. Yoo[b], S.A. Ahmed[c], R. Haining[d,*], S. Kadannolly[a]

[a] Department of Geography, Central University of Karnataka, India
[b] Department of Geography, State University of New York, Buffalo, USA
[c] Department of Applied Geology, Kuvempu University, Shankaraghatta, India
[d] Department of Geography, University of Cambridge, United Kingdom

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ABSTRACT

Spatial decision support systems have already proved their value in helping to reduce infectious diseases but to be effective they need to be designed to reflect local circumstances and local data availability. We report the first stage of a project to develop a spatial decision support system for infectious diseases for Karnataka State in India. The focus of this paper is on malaria incidence and we draw on small area data on new cases of malaria analysed in two-monthly time intervals over the period February 2012 to January 2016 for Kalaburagi taluk, a small area in Karnataka. We report the results of data mapping and cluster detection (identifying areas of excess risk) including evaluating the temporal persistence of excess risk and the local conditions with which high counts are statistically associated. We comment on how this work might feed into a practical spatial decision support system.

1. Introduction

Malaria is the most important parasitic disease of humans and one of the leading causes of morbidity and mortality in tropical countries (Roy et al., 2015). India, with a population in excess of 1 billion, has the largest number of people living at risk of malaria in South East Asia. It accounts for nearly 80% of all malaria cases in the region (Dev and Sharma, 2013). According to the World Malaria Report 2014, 22% (275.5 m) of India's population live in high transmission areas (>1 case per 1000 population), 67% (838.9 m) live in low transmission areas (0–1 cases per 1000 population) and 11% (137.7 m) live in malaria-free areas (0 cases). Whilst about 90% of India's population live in areas where malaria is endemic 80% of all reported cases occur in tribal, hilly and inaccessible areas containing 20% of India's population. Despite these challenges, India is working and making progress towards the elimination of malaria. Since 2000, the country has more than halved the number of malaria cases, down from 2 million to 882,000 in 2013 through expanding WHO-approved community based diagnostic testing, artemisinin-based combination therapies, providing durable bed-nets and implementing indoor spraying (NVBDCP website; WHO, 2012). Nonetheless India's public health system continues to face many challenges including implementation of surveillance and response programs to accurately estimate and control the national malaria burden (Das et al., 2012, Van Eijk et al, 2016).

In the year 2006, over 62,800 cases of malaria were reported in Karnataka state, a high transmission area, whilst in 2013, just over 13,300 cases were reported. The incidence of malaria in Karnataka is therefore also

* Corresponding author.
E-mail address: rph26@cam.ac.uk (R. Haining).

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showing a downward trend as in the nation as a whole. But whilst there is currently a global focus and dedication of resources towards elimination in India, malaria programs pursuing this goal within resource poor and remote settings in the country face significant challenges in meeting the operational requirements for sustainable reduction. A spatial decision support system (SDSS) offers the potential to contribute significantly to this effort in such areas. An SDSS, as its name implies, is a form of decision support system (DSS) consisting of a set of linked computer models (Cromley and McLafferty, 2012). However an SDSS has a number of distinguishing features: it supports spatial data input, capturing the spatial relationships and structures associated with spatial objects; it provides spatial analytical techniques; it supports output in various forms including maps (Densham, 1991). It supports spatially oriented planning by providing a platform to rapidly collect, store and extract essential data throughout key phases of program implementation; effectively manage and ensure essential services are delivered at optimal levels of coverage in target areas; actively locate and classify transmission to guide swift and appropriate responses (Kelly, 2013). If the SDSS is also being designed to support spatial epidemiology the spatial analytical techniques will include a Rapid Inquiry Facility (RIF) which is used for disease mapping and risk analysis by generating standardised rates and relative risk estimates for small areas (see http://www.sahsu.org/content/rapid-inquiry-facility).

Interactive SDSSs have proved their usefulness in malaria elimination in many countries (Daash et al., 2009; Srivastava et al., 2009; Wangdi et al., 2016). Public health practitioners (PHPs) new to geographic information benefit from enhanced interpretive support documentation when using internet-based, interactive public health atlases (Koenig et al., 2011). A prototype SDSS coupled with a Rapid Inquiry Facility (RIF) is currently being developed for Kalaburagi (formerly known as Gulbarga) district in Karnataka State. The SDSS will be used to improve public health and to enable better management of available resources. The RIF will be used by the district's local administrators to allocate resources more efficiently based on inputs provided by authorised Primary Health Centre employees as well as mobile app. users.

The main objective of this paper is to report the findings of work collecting and analysing small area malaria and other data in order to better understand the spatial-temporal geography of malaria from April 2012 to March 2015 in Kalaburagi taluk, an administrative unit, (also known as a tehsil) which consists of 139 spatial units with a total population of just under 800,000. We analyse the data in two-monthly time windows in order to assess the stability of relationships. This will be important if any system is to be developed which will be of help to health practitioners. However working at such fine spatial-temporal scales does raise the question of how to deal with small numbers. In reporting these results the paper also considers the analytical capability that will be embedded in the SDSS. The SDSS and RIF will be the subject of a second paper. We envisage a process in which as new data become available these data are subject to the same or similar analyses to the ones reported here thereby expanding the knowledge base contained within the SDSS/RIF. We will discuss the challenges associated with these activities in the concluding section of the paper.

2. Review of literature

In India, malaria endemicity is associated with diverse ecologies, multiple disease vector species and nine widely distributed anopheline vectors transmitting three plasmodial species: *P. falciparum, P. vivax,* and *P. malariae* (Sharma, 1998; Acharya et al, 2013). The states of Orissa, Chhattisgarh, West Bengal, Jharkhand, and Karnataka contribute the most cases (Kumar et al., 2007). Efforts to use environmental data for epidemic prediction and response began in the early 1920s in India (Myers et al., 2000). It has long been understood that mosquito numbers depend on climate and that meteorological variables can be used to predict the onset and severity of malaria epidemics (Gil, 1921, 1923).

Malarial incidence, its severity, temporal dynamics and spatial distribution are strongly determined by climatic factors, and in particular temperature, precipitation, and relative humidity levels which in turn are affected by altitude differences (Fanello et al., 2007, Dhara, 2013, Singh et al., 2009, Sipe and Dale, 2003, Srimath-Tirumula-Peddinti et al., 2015). Even small differences in climate can have very marked effects on the intensity of malaria transmission, even in areas subject to malaria control for many years (Kleinschmidt et al., 2001). The amount, intensity and duration of rainfall affect the size of the mosquito population (Russell et al., 1963). Rainfall also increases relative humidity (RH) and modifies temperature, which affects the longevity of mosquitoes and hence the transmission of the disease (Molineaux and Gramiccia, 1980). If RH is below 60%, the life of mosquitoes is shortened which in turn reduces disease transmission. RH values of 60–80% are considered to be optimum for the transmission of malaria (Pampana, 1969, quoted by Dhiman et al., 2008).

The maximum number of positive malaria cases are reported between May and October and this period coincides with substantial amounts of rainfall (Bhattacharya, Sharma et al., 2006). Research into malaria and monsoonal rains in the desert and semi-arid regions of India has shown that the maximum correlation between monthly cases and rainfall was obtained when rainfall was accumulated for the five to six previous months (Laneri et al., 2010).

The occurrence of malaria is bound closely to conditions that favour survival of the anopheles mosquito and the life cycle of the parasite. These conditions are determined predominantly by climatic factors, vegetation cover, and the vector's access to water surfaces for breeding (Kleinschmidt et al., 2001). The largest abundancies of mosquitoes, and disease outbreaks, are located in and around a 2.5 km buffer zone of water, wetland and cultivated areas and the type of vegetation which surrounds the breeding sites may also be important in determining the abundance of mosquitoes (Palaniyandi, 2012, Sipe and Dale, 2003, Wielgosz et al., 2012). Stagnant water is the commonest breeding place followed by ditches and ponds and even coconut shells can act as breeding places for these vectors (Boratne et al., 2010).