Mobile mapping for the rapid field assessment of health infrastructure and service provision in remote, rural eastern Indonesia.

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Brief Biography: Rohan Fisher has worked with satellite data and GIS for the last 19 years, initially for CSIRO in Canberra, and subsequently for the Northern Territory government in Alice Springs and Darwin. For the last 8 years he has worked as a Research Associate at Charles Darwin University focusing on GIS and Remote Sensing tools for natural resource management and good governance in the Eastern Indonesian province of Nusa Tenggara Timur (NTT). His current research and training work is focused on open-source applications for mobile mapping and health data visualisation in remote, developing country contexts.

Abstract

The rural population of eastern Indonesia generally has limited access to health services due to rugged topography, poor roads and limited health resources. Moreover there are no comprehensive audits of health infrastructure at the district level resulting in poor coordination of health resource allocation between levels of government. This project is using mobile field data collection techniques to identify gaps in health services and to enable more effective and equitable delivery of scarce health resources to remote and poor regions.

This study tested the assumption that recent changes in mobile mapping and GIS technologies have made them appropriate and effective tools for public health applications in rural, developing contexts. Three primary factors seen to be facilitating more widespread use were: (1) decreasing hardware costs, (2) the technological convergence of GPS/mobile-phone/PDA (personal digital assistant) hardware and (3) the development of free/open-source spatial data software. Through this project spatial data collection and visualization technology, normally considered the province of a techno-elite, was introduced to local health administrations in simple, intuitive and inexpensive forms. Through training, tailored to address local issues, capacity was developed amongst health staff (district and clinic levels) in the eastern Indonesian province of Nusa Tenggara Timur to collect and interpret data for improved health service delivery. This capacity is particularly important since recent political decentralization in Indonesia has given local government greater control over budgeting and planning.

This paper presents two examples of mobile mapping: (1) at the district level, of health infrastructure to inform resource allocation, and (2) at the clinic level, of pregnant women to ensure access to skilled health workers for birth. Through these activities the successful integration of simple field data collection and GIS tools for informing public health planning in low resource settings was demonstrated.

Introduction

GIS can be a powerful tool for improving the understanding of data through visualisation and analysis and is being increasingly used by public health professionals for planning, monitoring and surveillance. Moreover mapping data provides more insight than a table of the same data (Mujeeb, Shahab & Hyder 2000), and enables quick assessments of trends and interrelationships. Despite this potential, the use of GIS and mobile mapping technologies in developing countries is not widespread. There are perceived problems with GIS in low resource settings (Sipe & Dale 2003; Thomson et al. 2000); mapping technologies can be expensive and complex, the province of a techno elite; input data are often of low quality whilst presentation in a GIS can suggest veracity. However in recent years, due to decreasing hardware and software costs, there has been a revolution in the use of spatial data tools. This paper explores the theory, through work conducted in eastern Indonesia, that recent changes in mobile mapping and GIS technologies have made them appropriate and effective tools for public health applications in rural, developing contexts.

To test the ‘appropriateness’ of mobile mapping and GIS, this study implemented health mapping applications in partnership with local government in the remote eastern Indonesian province of Nusa Tenggara Timor (NTT). Eastern Indonesia faces the challenges of providing adequate and equitable health services to a largely rural population. Health in NTT is generally poor, with high rates of maternal and neonatal mortality (GOI 2009). Assuring access to trained health staff at the time of giving birth is seen as critical for reducing complications. However access is often difficult due to rugged landscape, poor transport infrastructure and limited health care resources.

In Indonesia, the responsibility for health service delivery is mainly at the district level. Due to decentralisation since 2000, there has been devolution of budgeting and planning responsibility to the district level (GOI 2007) without a corresponding provision of the base data and analysis skills required for evidence-based decision making. Currently, district and sub-district health officers collect and collate health data for analysis by ‘experts’ at the provincial or national level. Limited data analysis by clinic and district health staff means there is little quality assurance in the data collected. This study aimed to introduce tools for collecting accurate health data for informing effective service delivery through rapid field data collection processes for GIS visualisation and analysis.

The study area

NTT has a population of 4.2 million, and health facilities include 17 public and 12 private hospitals, 298 clinics (*puskesmas*), and more than 11,000 other local health facilities (*pustu*, *polindes*, *poskesdes* and *posyandu*) (NTT Health Dept data, 2009). The provincial health department has a role in coordination of health resources (staff and infrastructure) and systems for surveillance of health indicators. National government funding is allocated directly to the 21 city and district health departments for establishing and operating health clinics. Sub-districts can apply directly to the national government for funding to support health posts.

Mobile mapping was initially introduced to two study districts, Ngada, (Central Flores) and Timor Tengah Selatan (TTS, West Timor) with subsequent expansion into four more districts: East Sumba, East Flores, Kabupaten Kupang and Kota Kupang (Figure 1).

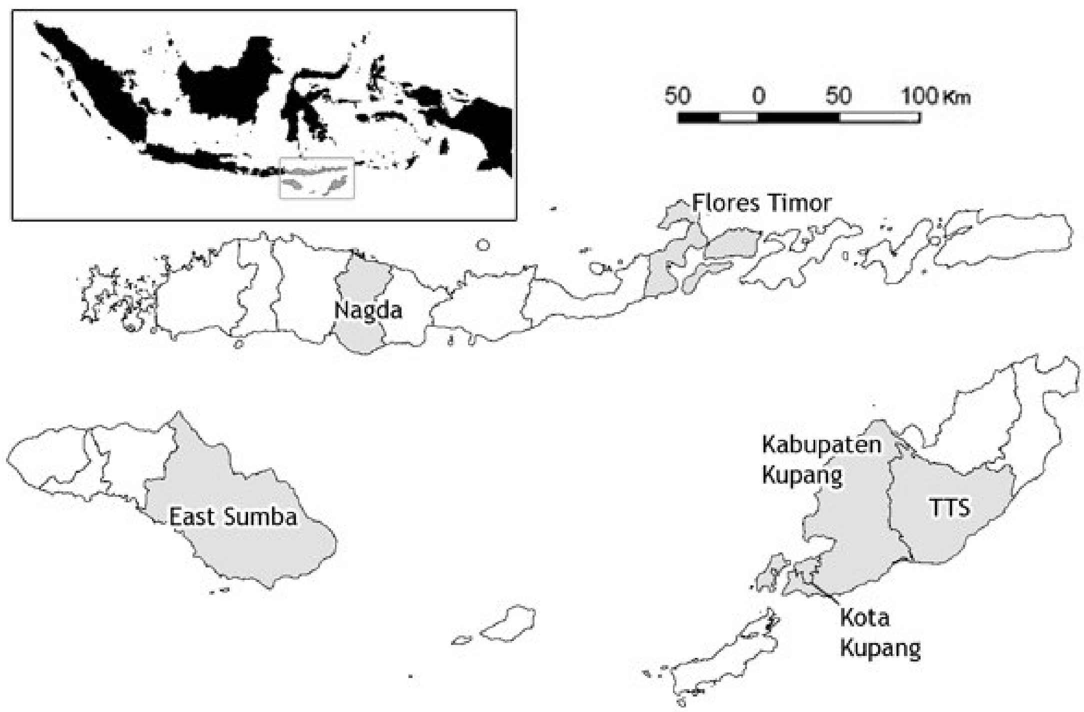

Figure 1. The province of Nusa Tenggara Timur with the six project study districts labelled.

Methods

Software and hardware tools were provided to the participating districts along with comprehensive training focused on specific applications with potential to inform the provision of health services.

Tools

Field data collection and spatial analysis tools were introduced to local health department staff to improve health infrastructure and patient data. To ensure the most affordable and sustainable implementation this study used only free or Open Source (OS) software and inexpensive hardware. The software applications were:

1. *Cybertracker***,** free software for field data collection on GPS enabled PDA's, used to collect health infrastructure data.
2. *Open Jump*, Java-based, open source GIS, used for health data visualisation and simple analysis.
3. *AccessMod*©, a free plug-in from World Health Organisation (WHO), for service availability mapping.

Mapping with *Open Jump* and service availability mapping with *AccessMod*© used both new data collected using *CyberTracker* and existing health data, available from routine reporting by clinic staff.

Cybertracker field data collection software ran on relatively inexpensive (~$300 US) mobile phone/PDA with integrated GPS (HTC Touch). Open Jump ran on low cost note and net books (~$400 US).

Training

An initial series of three day training workshops were conducted in the use of *CyberTracker* for field data collection and *Open Jump* for data visualisation and querying. The training examples and exercises used local data from each participating district. Six months after this initial workshop further training was provided to selected participants from each district in service availability mapping. For all training CD's were provided containing the required software, local spatial data, and video tutorials. The video tutorials used screen captured step-by-step instructions with Indonesian narration (http://healthpslp.cdu.edu.au/tute/). The material provided on CD allowed participants to continue self-training after each workshop. In some cases follow-up mentoring was provided to help with the development of the *Cybertracker* field collection data bases.

Applications

1. Rapid field data collection

There are no comprehensive audits of health infrastructure at the district level with varying levels of government responsible for funding various types of health services. This results in the potential for poor coordination of resource allocation among levels of government. In order to address this problem, Cybertracker databases were created to map the location of all clinics and community health centres, and record information about the staffing and infrastructure at these facilities.

Health clinics are the focus of primary health care delivery to most rural communities. Two clinics within Timor Tengah Selatan district used Cybertracker rapid field data collection to gather detailed patient data to assist with the planning of service delivery.

2. Mapping health indicators using Open Jump GIS software

Data collected using Cybertracker was subsequently exported for visualisation within Open Jump. The collected health infrastructure and patient data were mapped along with preexisting administration boundary and road infrastructure data. Additional health indicator data collated in district level health reports were also mapped in order to find possible correlations between health service provision and outcomes.

3. Service availability mapping using AccessMOD©

Access to health services is a primary determinant of health outcomes (Tanser & Sueur 2002). Travel time to health infrastructure is a commonly used measure of accessibility. AccessMOD calculates an estimate of travel time from homes to health facilities, taking into account terrain, land cover and transport infrastructure. The following variables influencing travel time were provided as spatial grids for input into AccessMOD:

- Slope as derived from a high resolution digital elevation model (DEM). These data were obtained as a free download from the ASTER Global Digital

- Landcover derived from Landsat imagery was produced as a grid with four categories savanna, scrub, forest and rivers.

- Transport infrastructure comprised road information which was classified into three categories of road quality; national, provincial and district. These data were obtained from the local department of planning.

The health infrastructure data (Clinics, Health posts, etc.), collected with Cybertracker, were used as the base data for which the ‘travel times to’ where calculated.

Results

District level Health Infrastructure mapping

Comprehensive health infrastructure maps were produced for both Ngada and TTS districts. A simple Cybertracker data entry sequence was created for collecting basic data including type of facility, infrastructure (electricity, water, beds) and staff (numbers of doctors, nurses, midwives). In Ngada two staff were allocated one motor bike to travel to all the district health centres to record these data. An audit of 176 health facilities over an area of 299 km^2 was carried out by these two staff members over 46 days, and the locations of these facilities were mapped using *Open Jump* software. A similar process was used in TTS. Through this activity, health department staff became aware of some health facilities in their district that they did not know existed before the field data collection. Staff in TTS and Ngada who have been trained are now mentoring staff in other districts in field data collection.

Service Availability Mapping

The maps of health infrastructure with travel time modeling are now being used in both Ngada and TTS to inform the allocation of resources by the district health departments. Figure 2 shows a one hour travel time radius around different levels of health services: Puskesmas (clinic), Community Health Clinic (Pustu) and Village midwife post (Polindes). Regions remote from basic health services can be clearly seen in this mapping. Not all health facilities provide the same services, for example access to emergency obstetric care (PONED) is available at only a few clinics (Fig 3). Modeling of service access based on specific needs increases the utility for informing the allocation of staff and infrastructure. In the past, staff allocations have been determined through recommendations based on staffing levels in each sub district without reference to access. Now maps of health staff are used to inform the allocation of new staff, as well as some funds.

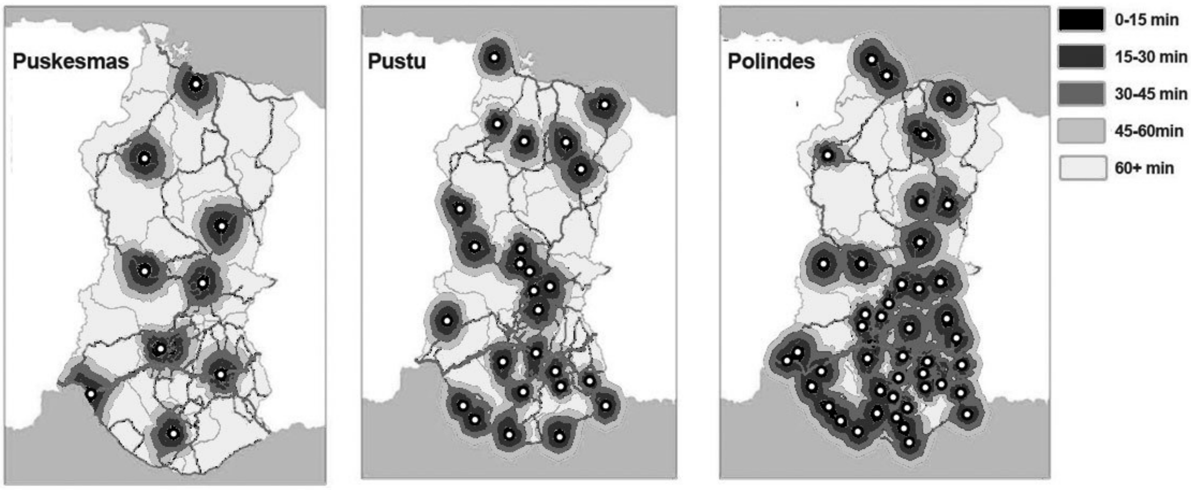

Figure 2. One hour travel time by foot and road transport around three levels of health infrastructure: Puskesmas (Clinic), Pustu (Community health center) and Polindes (Birthing center).

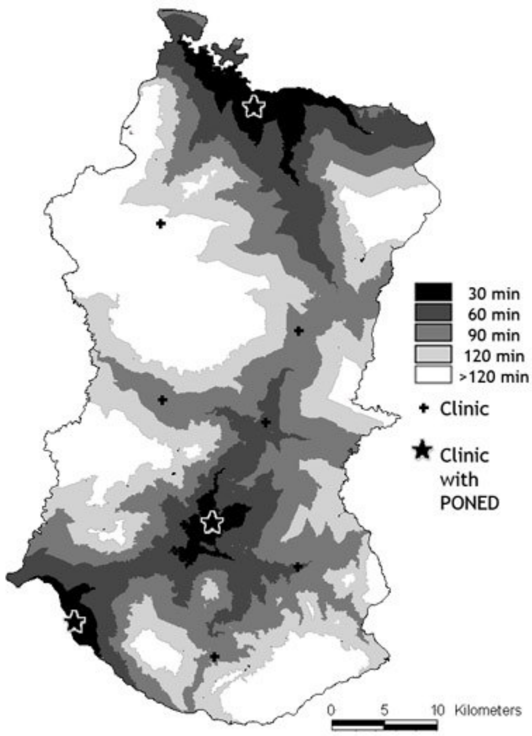

Figure 3. Two hour travel time to emergency obstetric care in Ngada district, central Flores.

Sub district (Clinic) level mapping

One clinic, in collaboration with local health department staff who participated in the mapping workshops, developed a project to improve access to maternal health services. Mapping was initially produced showing poor levels of maternal health service provision in some regions (Figure 4). In order to facilitate more effective provision of neonatal services and to assure access to trained health staff for birth, the location of all pregnant women in their sub district (n=217) was recorded along with period of gestation data (Figure 5). This location data were collected as part of other patient check-up activities so required little extra work. Normally information on pregnant women is stored as a card system recording important patient data; however the additional mapping of the women's location allowed for more efficient service provision. Busy mid-wives and other clinic staff were able to easily visualize priority areas and plan a more efficient check-up schedule. Moreover the maps enabled the efficient use of clinic transport services to assure that women were in a location with access to trained health staff for birth.

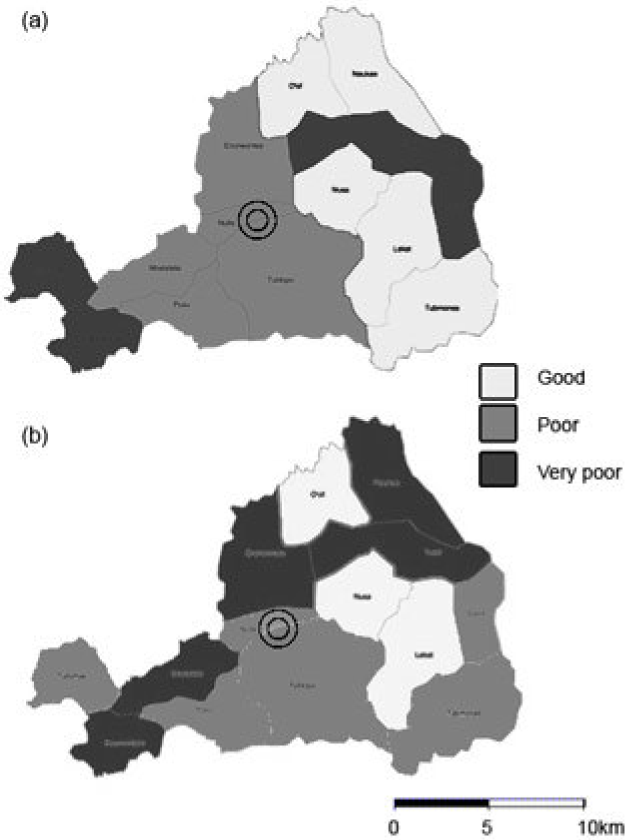

Figure 4. Access to Maternal health services in one sub-district in West Timor showing (a) coverage of women receiving comprehensive neonatal checkups during pregnancy and (b) the number of births attended by trained midwives.

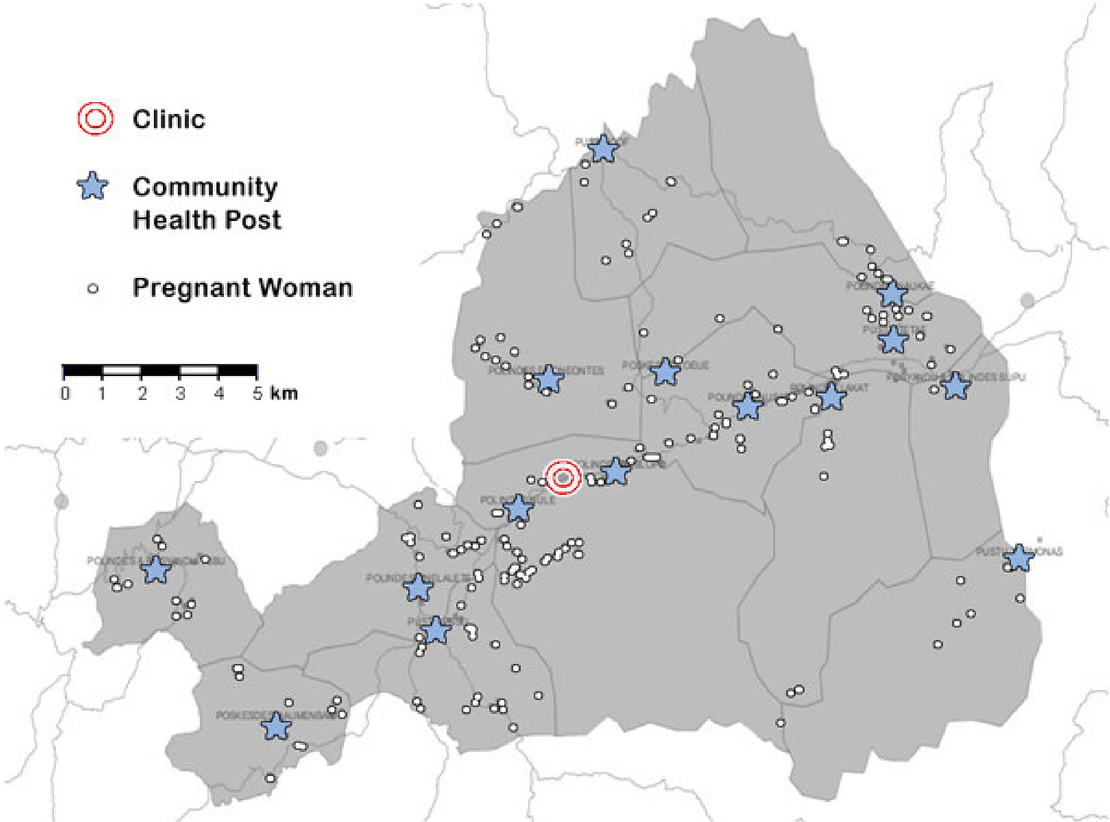

Figure 5. The distribution of pregnant women, and health infrastructure in one sub-district of Timor Tengah Selatan.

Discussion

This study has shown that by using free and simple software with clear training materials and low cost hardware, mobile health mapping can be a useful aid for health data analysis in low resource, rural settings. Health mapping is now being used in the eastern Indonesian districts of Ngada and TTS to inform the allocation of health staff and the location of new health infrastructure. For example, estimated travel time to basic emergency obstetric care is now informing the allocation of midwives and identifying the priority areas for upgrading emergency obstetric care facilities. This is an important development as early diagnosis is of primary importance for the successful treatment of maternal complications (Dogba & Fournier 2009). The Government of Indonesia has committed itself to improved maternal health primarily by increasing the number of births attended by skilled health providers (Ronsmans et al. 2001; Shankar et al. 2008) an ongoing process that could be assisted by the methods described here.

Local capacity to make timely maps of health data helps direct effective, targeted health service delivery (Booman et al. 2000; Nobre 1997). The independent development of the clinic level maternal mapping project was evidence of the appropriateness of the mobile mapping and GIS technology in terms of the utility of its application, the ease with which it could be integrated into current work practices and the way it could be further decentralised for practical use at the sub-district level. The ability for these technologies to assist in effective field data collection to directly assist local planning is also a key for improving data quality. The district level health department (TTS) is currently looking for opportunities to enable mobile mapping and GIS visualisation at other clinics.

Although the pilot studies were successful, some cautionary observations were made about the specific software and hardware used. Although reasonably intuitive it was found that database development with *CyberTracker* was limited to those with reasonably IT literacy. An Indonesian language version of the comprehensive *CyberTracker* database development tutorial was produced to enable continuing independent learning (http://healthpslp.cdu.edu.au/tute/). Accessing accurate base spatial data (ie. roads and administration) is currently difficult. Furthermore there is no official process for sharing collected spatial field data between different levels of government. This could result in less accurate data, than available at the local level, being used for the implementation of national or international programs. However good quality local data with visualisation and presentation skills could allow for more effective advocacy for appropriate health care support from the district level upwards.

Conclusion

This study has shown how the technological convergence of GPS/mobile-phone/ PDA hardware is decreasing the costs and increasing the reliability of mobile mapping making it an appropriate tool in low resource settings. Simultaneous with this development is the evolution of a range of free and OS software solutions for spatial data collection and processing. OS software is of particular interest to developing countries where resources are limited and licensing costs can be prohibitive. The free and unlimited distribution of OS software, and its ability to import a broad range of pre-existing data formats, makes it an attractive alternative to expensive proprietary packages (Câmara, 2004). Future developments could see the linking of mobile mapping with SMS based data maintenance systems, such as Frontline SMS (FRONTLINESMS 2010), whereby mobiles phones are used not only to map field data but also provide continuous near real time field updates. This system would allow disease outbreaks and medicine stocks to be monitored and spatially visualized for quick, targeted response.

This study has presented a successful application of spatial tools for health data visualisation and analysis. Although this approach can increase data understanding it does not by default lead to critical thinking. The ability to question the veracity of data, search for correlations, trends or inconsistencies are skills that need to be actively taught alongside the more technical competencies. Although the results to-date have been promising, the broader acceptance of GIS for guiding policy and program development in local government will require ongoing demonstration of the utility of these tools, and a willingness to embrace evidence-based decision making in a complex political context.

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