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Integration of population census and water point mapping data—A case study of Cambodia, Liberia and Tanzania

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ABSTRACT

Sustainable Development Goal (SDG) 6 has expanded the Millennium Development Goals' focus from improved drinking-water to safely managed water services. This expanded focus to include issues such as water quality requires richer monitoring data and potentially integration of datasets from different sources. Relevant data sets include water point mapping (WPM), the survey of boreholes, wells and other water points, census and household survey data. This study examined inconsistencies between population census and WPM datasets for Cambodia, Liberia and Tanzania, and identified potential barriers to integrating the two datasets to meet monitoring needs. Literatures on numbers of people served per water point were used to convert WPM data to population served by water source type per area and compared with census reports. For Cambodia and Tanzania, discrepancies with census data suggested incomplete WPM coverage. In Liberia, where the data sets were consistent, WPM-derived data on functionality, quantity and quality of drinking water were further combined with census area statistics to generate an enhanced drinking-water access measure for protected wells and springs. The process revealed barriers to integrating census and WPM data, including exclusion of water points not used for drinking by households, matching of census and WPM source types; temporal mismatches between data sources; data quality issues such as missing or implausible data values, and underlying assumptions about population served by different water point technologies. However, integration of these two data sets could be used to identify and rectify gaps in WPM coverage. If WPM databases become more complete and the above barriers are addressed, it could also be used to develop more realistic measures of household drinking-water access for monitoring.

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1. Introduction

After the expiry of the United Nations' Millennium Development Goals (MDGs) in 2015, the international focus on water and sanitation has shifted to a broader agenda through the Open Working Group of the General Assembly's Sustainable Development Goals (SDGs) (United Nations General Assembly, 2014; WHO and UNICEF, 2015a). The ongoing development of indicators for enhanced monitoring of progress towards the SDG targets is likely to place greater demands on existing datasets. For example, percentage of population using safely managed drinking water services has been adopted as an indicator for SDG Target 6.1 (which aims to 'achieve universal and equitable access to safe and affordable drinking water for all') (WHO and UNICEF, 2015a; Division for Sustainable Development of UN-DESA, 2016). This suggests a need to integrate population-based data on household drinking water with information on water service levels related to the Human Right to Water and Sanitation (United Nations General Assembly, 2010), including quality, accessibility and availability (WHO and UNICEF, 2015a). When used in isolation, conventional data sources may not be able to meet the expanded demand for more sophisticated international monitoring.

Population census data have long been used alongside household surveys for MDGs monitoring of access to drinking water and sanitation. Censuses can be disaggregated spatially to a greater extent than household surveys (Yu et al., 2014), which facilitates their integration with other spatial datasets. However, household water sources are often classified inconsistently from country to country, census enumeration is typically decadal and population census content is restricted to core household characteristics only, for example, excluding water quality (Yu et al., 2016). Moreover, in

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low and middle income countries (LMICs), census small area statistics are often not publicly available. Where data are made available, they are frequently provided as aggregate data for relatively large administrative units rather than for small areas or as micro-data with codes for provinces or districts (Ruggles et al., 2003), for data protection reasons.

The introduction of the SDGs has coincided with increased availability of alternative datasets relevant to safe drinking water access, including water point mapping (WPM). As a process, WPM involves data collection and mapping, storage, processing and analysis, relating to individual water supply points (Welle, 2007; Shantz, 2013). The water point inclusion criteria and characteristics recorded in WPM vary depending on a project's purpose. However, characteristics often include information on location and type of water point, functionality, construction information, perceived water quality, service sustainability, and other relevant characteristics. In many WPM exercises only perceived, aesthetic water characteristics are recorded (Welle, 2005; Liberia Ministry of Public Works and Liberia WASH consortium, 2011). However, in a few cases (Coast Water Services Board, 2013; Shantz, 2013), micro-biological or chemical parameters (e.g. *E.coli*, fluoride, or arsenic) are tested to assess source safety. In addition, when microbiological or chemical tests are generally considered expensive, an enhanced water point mapping (EWPM) approach has been developed to assess water contamination at a reduced cost (De Palencia and Pérez-Foguet, 2012). In addition, although WPM data collection is sometimes centrally coordinated by government, data are often collected by a diverse range of organisations, including NGOs, so data collection protocols can be similarly diverse. The introduction of a WPM data exchange (WPDx) and related Data Exchange Standard has facilitated the standardisation of such data (Global Water Challenge, 2014) and the exchange now includes approximately 244,000 data points from 25 countries.

While population census data provide spatially disaggregated data that describe both household water sources and socio-economic characteristics, water point data could provide greater temporal resolution and supplementary information, for example, concerning water safety management, quality or quantity. However, the diversity of organisations and projects generating WPM data, along with their differing objectives, may lead to incomplete and spatially biased coverage. The future utility of WPM data will depend on our ability to integrate it with other data sources, such as population censuses. This study therefore aims to (1) quantify the apparent differences in population served by specific water source types, based on population census versus water point data (as a proxy for completeness of WPM coverage); (2) examine potential barriers to integrating population census and water point data to meet SDG monitoring needs; and (3) evaluate the potential insights into household water use and monitoring that may be gained from integrating these two datasets.

2. Methods

2.1. Study countries and data

This study examines three case study low income countries: Cambodia, Liberia and Tanzania (Fig. 1), chosen for their relatively detailed population census content on water source categories (Yu et al., 2016) identifying a household's main drinking water source, and the availability of extensive WPM data. Geo-referenced Cambodian population census 2008 data were obtained from Open Development Cambodia (http://www.opendevelopmentcambodia.net/). These data consist of four administrative levels: 1 (province); 2 (district); and 3 (commune) as vector polygons; and level 4 (village) as vector points. The water point data for Cambodia were obtained from Cambodia WellMap (http://cambodiawellmap.com/) which includes 59,759 records of drilled, dug and combination well water points, originally sourced from several non-governmental organisations (NGOs) and government entities. Tabular data for households by main source of drinking water in Liberia were obtained from the 2008 Liberian population census (Liberia Institute of Statistics and Geo-Information Secvices, 2011). The Liberia 2011 WPM dataset was acquired from WASH Liberia (http://wash-liberia.org/), and consists of 10,001 improved water points (data submitted date from 2010 to 2011), with associated demographic data (population and household numbers) from the 2008 population census at administrative level 1 (county). For Tanzania, population census 2012 data were obtained from the Tanzania National Bureau of Statistics portal (http://www.nbs.go.tz/); water information at administrative level 2 (district) was derived from their regional basic demographic and socio-economic profiles. Tanzania water point data were acquired from the WPDx portal (http://waterpointdata.org/; data acquired: 25 January 2016), covering 23,352 records contributed by different data collection organisations in 1978, 1982, 2002–2009, and 2013–2014, but having excluded water points with missing GPS coordinates.

2.2. Water point data pre-processing

In order to match water point data with population census data, the initial database was filtered to remove disused or non-domestic water points and those constructed following census enumeration. Water points that met any of the following criteria were therefore removed: (1) water points recorded as disused (e.g. abandoned, closed due to lack of payment, etc.); (2) water points installed after the census enumeration date; (3) water points recorded as serving a facility or workplace (e.g. school, health centre, place of worship, etc.) rather than households; (4) water points used for purposes other than household drinking water (e.g. cattle troughs). Water points with ambiguous characteristics were retained. (Detailed characteristics used to identify water points for exclusion were listed in Supplementary Information A.)

Water point coordinates were used to link WPM data with census data at the commune level (administrative level 3) in Cambodia, county level (administrative level 1) in Liberia, and district level in Tanzania (administrative level 2). Water points lacking coordinates and those with implausible coordinates (e.g. outside national boundaries or in the sea) were excluded. Where there was a mismatch between GPS coordinates and recorded administrative area, administrative area information (name, ID) was corrected according to the GPS location.

Besides location, WPM and census data linkage required definitional matching of their respective water source classifications. WPM classifications were generally more detailed. For example, Tanzanian water point data contained information such as the original source of water (e.g. groundwater, surface water, rainwater), type of water point (e.g. standpipe, hand pump, etc.), and water extraction or lifting system (e.g. Afridev hand pump, electrically driven mechanised pump, gravity scheme, etc.). In comparison, water source categories in population census data were user-based and generally less detailed.

The Cambodian WPM data contained three different types of well water point categories, namely drilled well, dug well, and combination well (e.g. an open-well constructed above an underlying tube-well), whilst the Cambodian population census differentiated protected dug wells, unprotected dug wells and tube wells. Since water point data do not distinguish protected dug wells from tube wells and since combination wells could not be unambiguously placed into the tube well or dug well category, these three

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