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A participatory methodology for future scenario analysis of sub-national water and sanitation access: case study of Kisumu, Kenya

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ABSTRACT

This study pilots a participatory methodology for sub-national spatial planning of urban and peri-urban water and sanitation services. Three groups of key informants were presented with evidence on national historic and future service provision trajectories and asked to map water and sanitation access in the city of Kisumu, Kenya, by 2030, assuming current trends continue. Comparison of the groups' outputs suggests greater certainty among participants regarding service access in Kisumu's urban core compared to peri-urban areas. We discuss extensions to this preliminary methodology, including the potential benefits of its application to Kenya's rapidly expanding small towns as suggested by participants.

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Introduction

The long-term sustainability of urban water supplies is a strategic concern in many countries (UN-Habitat, 2016), given the pressures on water service providers arising from rapid urbanization, climate change, and the growing demands on both surface and groundwater resources, particularly from agriculture (Hoekstra, Mekonnen, Chapagain, Mathews, & Richter, 2012). One study examined the water sources supplying piped systems in 70 African urban areas in the 1970s and again in the 1990s and found that the urban water supply footprint expanded during this period, with water supplies increasingly being drawn from more distant rural areas by the 1990s (Showers, 2002).

To provide a basis for long-term planning of urban water and sanitation services, both modelling approaches and scenario planning have been used, particularly at the continental or global scale. One model combining demographic change scenarios via gridded population surfaces with climate and land-use change scenarios for developing-country cities estimated that the urban population in areas of perennial water shortage would grow from 150 million to almost 1 billion by 2050 (McDonald et al., 2011). The

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estimated population currently living in water-stressed cities was subsequently revised downwards when urban water supply infrastructure was included in the calculations; the original calculations assumed that urban dwellers used water near where they live, but the infrastructure used to supply water in urban areas is extensive, and urban supply systems often rely on water sources far from the urban area (McDonald et al., 2014). Scenario-based studies rely on a scenario as a 'hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points' (Kahn & Wiener, 1967, p. 6) and have been used for national water-sector planning (Hussein, 2002; Makropoulos, Memon, Shirley-Smith, & Butler, 2008). One widely used software package, International Futures, has been used to develop future scenarios for global infrastructure development, including that for water and sanitation (Rothman, Irfan, Margolese-Malin, Hughes, & Moyer, 2014). The software implements an inter-sectoral, multinomial model of infrastructure development, with forecasts combining actual (current) levels of infrastructure with assumptions about how the level of infrastructure is likely to change in the future. The software relies on various national data-sets often generated by the United Nations, so has only been implemented at national or occasionally at provincial levels (van der Lingen, Nonyati, Rafa, & Camp, 2015). For water and sanitation access, these assumptions are driven by a multinomial regression model with covariates including average income, the population living on less than $1.25 per day, public spending on health as a proportion of GDP, and mean years of education among adults (Rothman et al., 2014).

In Sub-Saharan Africa, more than two-thirds of countries have implemented one or more decentralization reforms, including Kenya, Ghana and Uganda (Awortwi, 2010), meaning that planning often now takes place at the sub-national level. However, fewer scenario-planning studies have focussed on the sub-national level and incorporated a spatial dimension in the future scenarios examined. Scenario planning has been used with geographic information systems to explore the hydrological consequences of urban development in the US (Binford & Saarinen, 2009), but examples in developing countries remain rare and have generally been rural (e.g., Cinderby, De Bruin, Mbilinyi, Kongo, & Barron, 2011). Given the decentralized planning structures in many Sub-Saharan African countries, there is thus a need to develop pragmatic approaches to support sub-national strategic planning.

To address this need, this study pilots and evaluates a methodology for translating scenarios developed at regional and global levels into specific land-use patterns at a sub-national scale. In doing so, it also seeks to map potential future patterns of population growth and household water and sanitation access in the city of Kisumu in Kenya, assuming continuity of existing trends and policies, and to assess their implications for strategic planning of services.

Methods

Study area

The Kenyan framework for delivering water and sanitation services was recently revised through the 2016 Kenya Water Act (Figure 1). Kenya's 2010 Constitution acknowledged access to safe water as a human right, assigning responsibility for water and sanitation service provision to the country's 47 counties. The subsequent Water Act

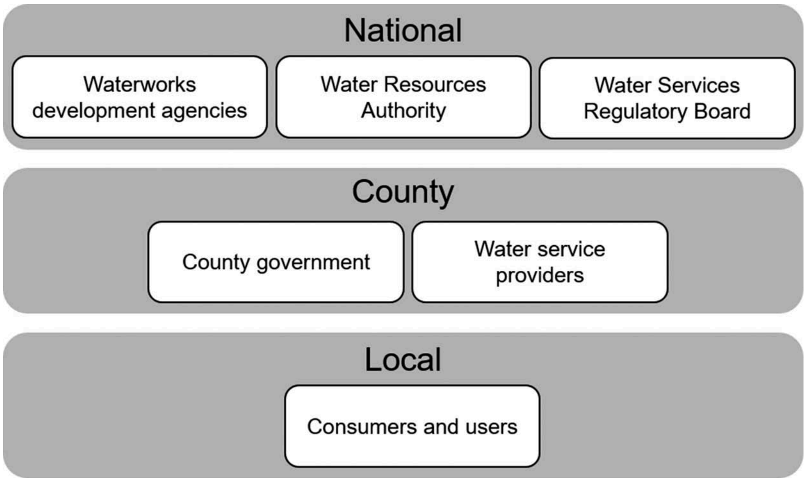

Figure 1. The Kenyan multi-level framework for delivering water and sanitation services (based on the 2016 Kenya Water Act).

differentiated national and sub-national responsibilities, for example mandating the Water Resources Authority to implement a national water resources strategy, with the Water Services Regulatory Board regulating and monitoring water and wastewater services nationally. County governments now oversee water service providers, who are responsible for service provision at the county level, with the Water Works Development Agencies coordinating cross-county public water works.

This legislation separated institutional responsibility for water resource management from service delivery, with institutions such as the Water Resources Authority being responsible for the former and the Lake Victoria North and South Water Services Boards for the latter. Simultaneously, the act devolved service planning from national to county government and made provision for greater community and user involvement in service planning (Marks & Davis, 2012). Nationally, the "Kenya Vision 2030" document provides a strategic plan for economic, human and infrastructure development (Government of Kenya, 2007). The impact of climate change on future water scarcity remains complex and uncertain, with one recent study based on 21 global circulation models suggesting anywhere between zero and 19% of East Africa's population becoming affected by water scarcity by 2050, and between zero and 18% simultaneously moving out of water scarcity (Gosling & Arnell, 2016).

The history of Kisumu has been described elsewhere (UN-Habitat, 2005), but in brief, the city has a central core with formal service provision, originally planned for the European population. This is surrounded by neighbourhoods originally designated for the African population, some of which are unplanned (Figure 2). Since the Water Act came into force, the Kisumu Water and Sewerage Company (KIWASCO) has had responsibility for service delivery across the city (Sima, Kelner-Levine, Eckelman, McCarty, & Elimelech, 2013). KIWASCO has a short-term action plan (for 2015–21), which includes plans to rehabilitate some 22 km of existing water supply networks and their extension into the informal settlements of Nyalenda and Manyatta, as well as rehabilitation of some of the city's wastewater treatment

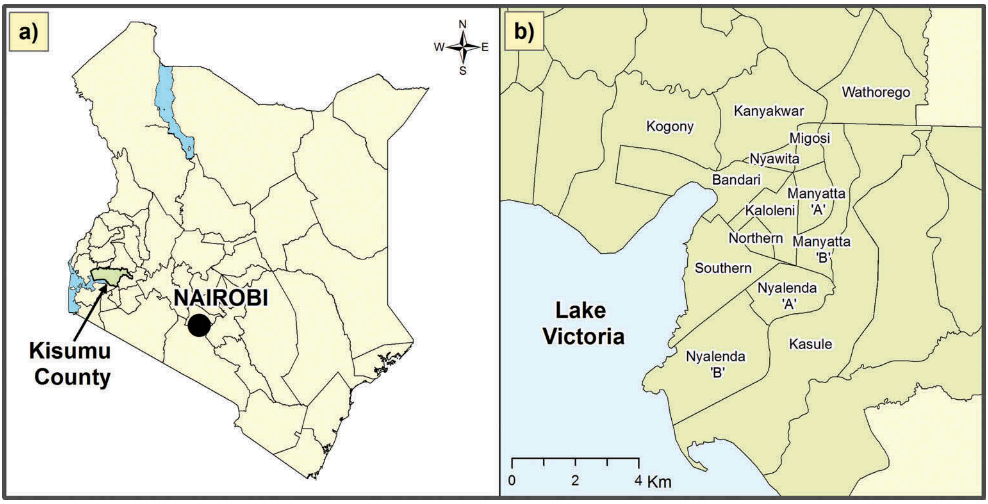

Figure 2. (a) Counties of Kenya (outlined in black), with the location of Kisumu County labelled in relation to Kenya's capital, Nairobi; (b) key sub-locations of Kisumu referred to in this study.

facilities at Kisat and Nyalenda. KIWASCO's long-term action plan (for 2027–40) includes plans for the construction of a new water treatment works at Kajulu and expansion of sewerage networks and wastewater treatment capacity. An emergency plan which entailed an additional phase introduced to bridge the time gap between the short-term and long-term plans was expected to increase the capacity of the Dunga source from 24,000 m^3 to 45,500 m^3. Some of these plans have already been implemented, while others are in progress for completion and commissioning within the current medium-term plan and the Kisumu County Integrated Development Plan period. Despite these plans, between 2002 and 2014, use of on-site sanitation has intensified in high-density settlements, and shallow groundwater sources continue to be used to supplement domestic piped water in response to lack of planned sewerage, cost of piped-water tariffs and other factors (Okotto-Okotto, Okotto, Price, Pedley, & Wright, 2015).

Key informant workshop

Twelve key informants, with particular insights into the water and sanitation sector, social and economic planning and human population dynamics in Kisumu County, were selected through purposive and referral sampling via contacts known to local members of the research team. Informed consent was sought from all participants to take part in a one-day participatory mapping workshop in July 2014. The participants were drawn from government offices, academia, service providers, and community-based or other non-governmental organizations working in and around Kisumu County and the local community members. Ethical approval for the study was obtained from the University of Southampton (ref no. 11148).

The workshop was divided into two sessions. In the first session, participants were given background information relevant to future trajectories of population growth and water and sanitation service provision and the potential challenges, such as water pollution, in Kisumu County. First, historic patterns of population density and household water and sanitation access were presented, derived from population census data for 1989 and 2009 (Government of Kenya, n.d.). Participants were given reference copies of the 2009 population density and household water and sanitation access maps to inform subsequent future scenario-building. Second, International Futures was used to access three preprepared national scenarios for water and sanitation access in urban Kenya. The first of these scenarios was based on the International Futures base-case scenario (Rothman et al., 2014), which assumes that present trends and policies continue and models consequent water and sanitation access using multinomial regression (Figure 3). A second, 'stagnant' scenario was presented, where water and sanitation access stayed at 2010 levels (Eshbaugh, Firnhaber, McLennan, Moyer, & Torkelson, 2011). A third, 'aggressively improved' scenario (Eshbaugh et al., 2011) mimicked the improvements in water and sanitation access of the best-performing countries of Sub-Saharan Africa (Malawi, Burkina Faso and Ghana for water access and Angola, Madagascar and Ethiopia for

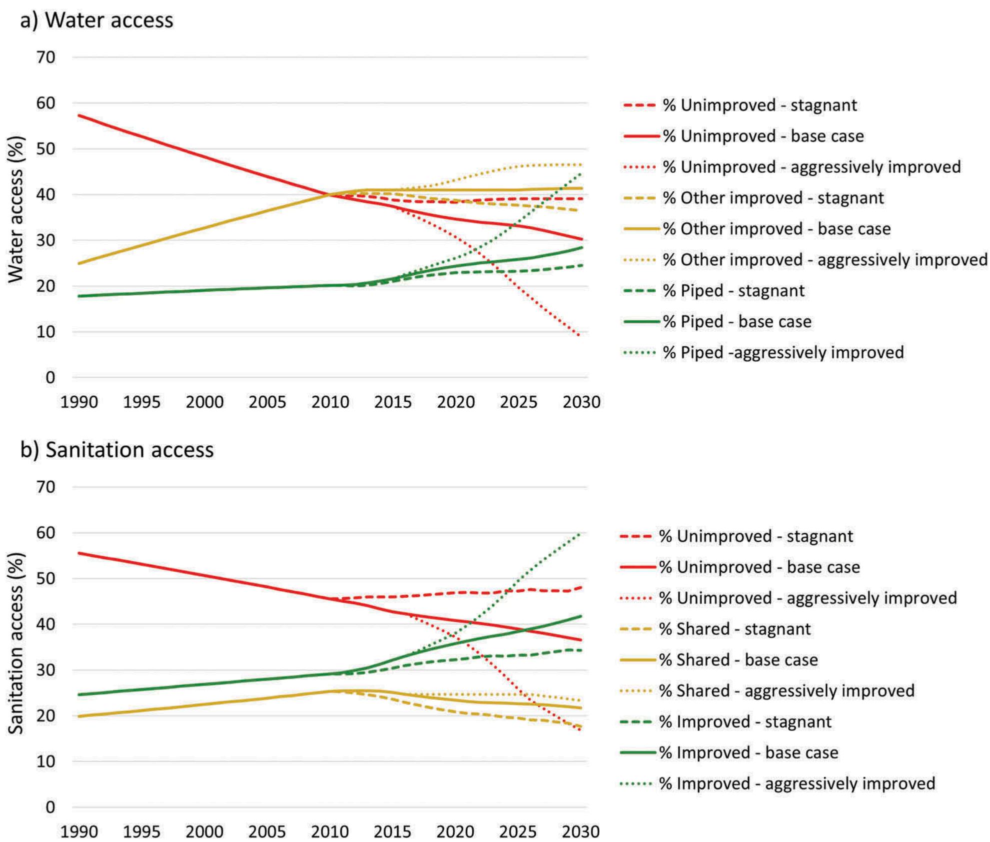

Figure 3. Past and future scenarios for 1990–2030 for Kenya for (a) population access to unimproved, other improved and piped water sources and (b) population access to unimproved, shared and improved sanitation facilities, based on model runs using International Futures with 'base case', 'aggressively improved' and 'stagnant' scenarios (Eshbaugh et al., 2011; Rothman et al., 2014).

sanitation), applying a 1.9% annual reduction of the number of people with no access, based on the average annual improvement in these countries. For the workshop, the 'stagnant' and 'aggressively improved' scenarios were called 'worst' and 'best', respectively, for clarity. A third presentation focussed on research evidence surrounding water quality and quantity and sanitation service delivery in urban Kenya. Finally, participants were given an overview of utility plans for immediate and longer-term water and sanitation service delivery based on KIWASCO's short-term and long-term action plans as described above.

Following these presentations, participants were split into three groups, each containing key informants drawn from different sectors. In this second session, the scenario-mapping process was explained to participants to enable them to consolidate the information gathered from the background presentations and then develop a consensus view (in their group) of plausible future spatial patterns of each thematic issue (population density and water and sanitation access). Each of the groups was then given transparencies superimposed on a hardcopy of a WorldView-2 high-spatial-resolution satellite image, showing the 14 sub-location boundaries (Figure 2). Based on the information about local service delivery plans, national projected trends, and relevant research on delivery of such services in Kenya, as well as their own knowledge of the sub-locations' tenure arrangements, demand for services, community cohesion and other issues they deemed relevant, each group was then asked to map out patterns of population density and household water and sanitation access by 2030. This outlook aligned well with the planning horizon of the Vision 2030 strategy document (Government of Kenya, 2007) and the Sustainable Development Goals. The Vision 2030 document sets out three pillars (economic, social and political) for transforming Kenya into a middle-income country, with the social pillar explicitly including a focus on water and sanitation provision. In doing so, each group was given a consistent set of categories and related colour codes for population density (low: <5 people/ha; medium: >5 and ≤50 people/ha; high: >50 and ≤100 people/ha; very high: >100 people/ha), household water access (>50% of households using water piped to dwelling, yard or standpipe or vended piped water; >50% of households using wells, springs, boreholes or vended groundwater; >50% of households using surface water such as ponds, streams, dams or rivers; mixed, where none of these three source types predominated) and household sanitation access (>50% of households with sewered connections; >50% using on-site sanitation such as septic tanks or pit latrines; >50% with no facility, buckets, or 'flying toilets' [defecation in plastic bags]; mixed, where none of these three forms of sanitation access predominated). Similar categories were used to present historic population density and household water and sanitation patterns, as described above. Participants were asked to forecast conditions by sub-location (the smallest areas used in Kenyan census geography), making assumptions analogous to the International Futures baseline scenario (i.e., continuation of the current path of development). Finally, each group described their predictions and explained the rationale for these, with a subsequent opportunity for groups to revise their maps, based on the viewpoints expressed by the other groups. Minutes of these discussions were recorded, and following the meeting, the maps drawn on transparencies were digitized and georeferenced in a geographic information system.

Cohen's kappa, a statistic commonly used to assess agreement between categorical variables (Watkins & Pacheco, 2000), was then calculated to assess levels of agreement across the three break-out groups, assigning different sub-locations to each of these predefined categories using the Stata statistical software package (StataCorp, 2013). To measure consistency of scenarios across groups spatially, we also calculated the number of pairs of groups that agreed on forecast categories. With three separate breakout groups forecasting three different variables, the minimum possible number of concordant pairs of forecasts was zero, and the maximum, nine.

Results

Expert consultation

All three groups were able to assign population density and water or sanitation service categories for the year 2030 to at least 12 of Kisumu's sub-locations, though Group 1 consistently assigned categories to more sub-locations than Groups 2 or 3. The Manyatta A and B, Nyalenda A and B, and Nyawita sub-locations were consistently identified as having very high population density by 2030 (Figure 4). The higher-income Southern, Northern and Kaloleni sub-locations were consistently classified as having mostly piped (Figure 5) and mostly sewered (Figure 6) connections by 2030. There were discrepancies (however small) about everything else.

Examining the consistency of scenario outputs across the three break-out groups spatially, the greatest consistency was in the urban core, where Northern and Kaloleni had seven pairs of consistent predictions. The consistency of scenario outputs was lowest in more peripheral, peri-urban areas such as Kogony and Kanyakwar, which had zero and two pairs of consistent predictions, respectively.

Overall, there was no significant agreement between the three groups in their classification of sub-locations with future water service categories (overall $\kappa = -0.06$; $p = 0.70$) and their use of future sanitation service categories (overall $\kappa = -0.01$;

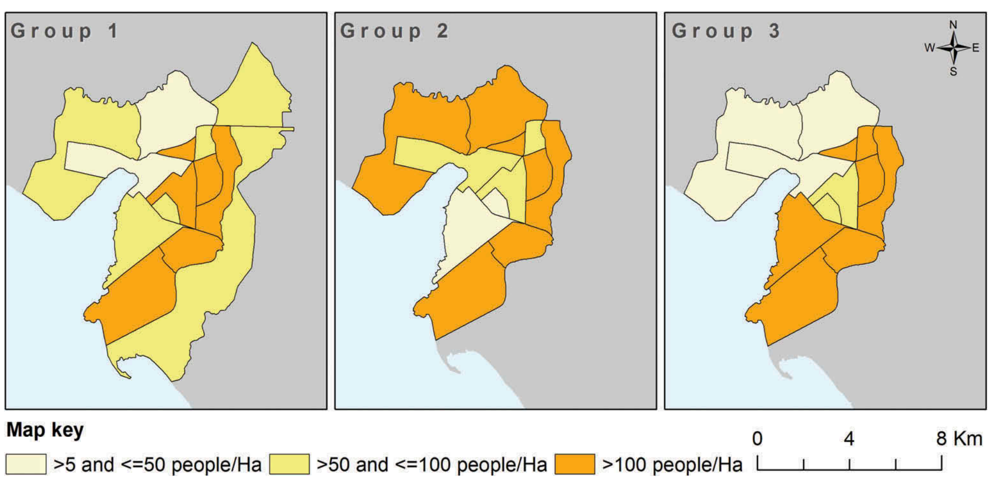

Figure 4. Map of population density by 2030 for sub-locations in and neighbouring Kisumu, Kenya, assuming continuity of current trends and policies, as envisaged by break-out groups 1, 2 and 3.

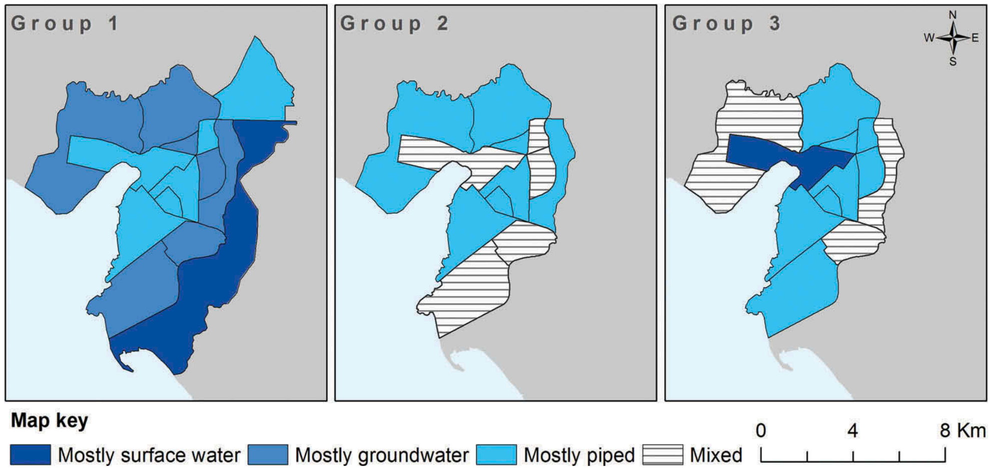

Figure 5. Map of household water access by 2030 for sub-locations in and neighbouring Kisumu, Kenya, assuming continuity of current trends and policies, as envisaged by break-out groups 1, 2 and 3.

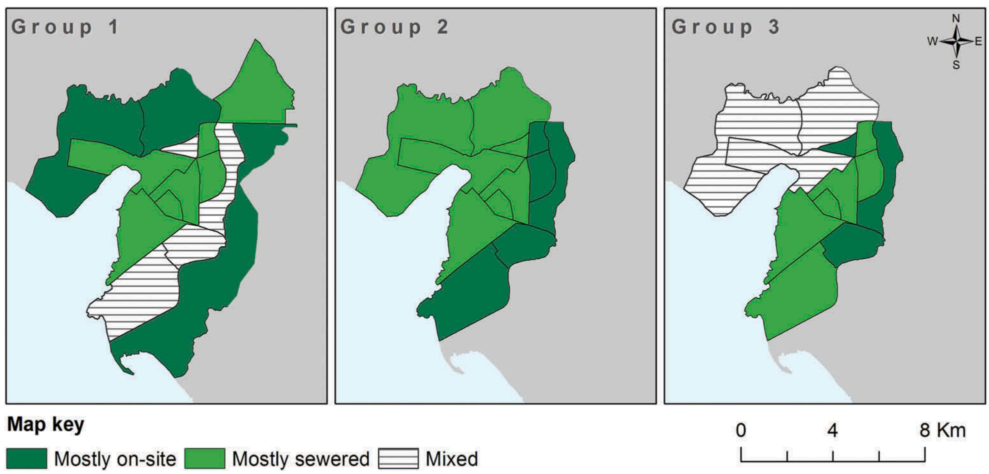

Figure 6. Map of household sanitation access by 2030 for sub-locations in and neighbouring Kisumu, Kenya, assuming continuity of current trends and policies, as envisaged by break-out groups 1, 2 and 3.

p = 0.53). There was however significant but modest agreement in the three groups' assignment of population density labels for 2030 to these sub-locations (overall $\kappa = 0.25$; $p = 0.02$).

In presenting the rationale for the scenarios they put forward, Groups 2 and 3 noted that several areas, particularly Northern, were already so densely developed that there was little scope for further population growth. Group 3, whose members had particular insights into urban development plans, noted the likelihood of Southern becoming more densely populated through planned high-rise lakeside development and likely densification of Manyatta A following planned piped network upgrading. Group 2 highlighted terrain as a particular barrier to sewerage and piped water delivery in Nyawita, while Group 3 noted that in some areas (e.g., Obunga) a lack of community cohesion and demand for improved water and sanitation were likely to persist as barriers to service delivery. All groups noted that demand for improved sanitation was lower than for improved water, leading to greater pessimism regarding future household access to sanitation. Projecting forward, all groups also noted the physical (topography and high density of existing housing) and land-tenure-related (illegality of much of the housing stock, i.e., lack of land titles) obstacles to installing sewerage connections in high-density informal settlements.

Discussion

Evaluation of scenario-planning methodology

Given the decentralization of local government in many parts of Africa, we argue that there is a need to give local planning bodies decision-support tools that can be used to evaluate sub-national future scenarios and thereby inform strategic planning. We have piloted the use of one such approach here. Participatory mapping has previously been used to map current conditions and service availability, including with community groups in Kisumu (Karanja, 2010). Our study applies such an approach to future scenarios.

An alternative to our participatory approach would be to use a quantitative future scenario modelling approach such as International Futures at sub-national level, as has been done for Western Cape Province, South Africa (Moyer, Neill, & Rafa, 2013). However, while the UNICEF and World Health Organization Joint Monitoring Programme has provided national estimates of household water and sanitation access since 1990 (Bartram et al., 2014), there remain barriers to acquiring equivalent sub-national data for scenario model calibration. Some sub-national data sets, such as the IBNET database of utilities (Moffitt & Danilenko, 2014), have emerged only recently and contain only short time series on local utilities such as KIWASCO. Where other relevant sub-national data sets are available, they are often affected by changes in sub-national administrative boundaries, which are typically less stable than national boundaries.

In this piloting of our methodology, the research team decided on presentations to provide contextual background to scenario mapping. The research team also chose sub-locations as spatial planning units, the study area, and neighbourhood characteristics to focus on (i.e., population density and access to water and sanitation) and provided predefined categorical labels for these neighbourhood characteristics. All of these workshop implementation decisions could have affected the outcomes of the exercise: for example, an additional population density category might have led to less apparent agreement between groups over future population-density patterns. Rather than a single participatory workshop, were a series of workshops to be held, it would be possible for a group of participants to define each of these aspects of the exercise according to their own priorities, for example deciding how many population-density categories should be used and where the breaks between categories should be. Such an approach would be in keeping with other participatory planning methodologies, but there would be greater demands on participants' time. Here, participants were generally enthusiastic about the exercise and were rapidly able to begin exploring future patterns of service access following initial briefing. One group, however, departed in some areas from using the sub-location boundaries provided for the exercise, because they believed there would be variation in future service access within some sub-locations, implying that areal units developed by the participants themselves might have been more appropriate.

Implications of the exercise for strategic service planning in Kisumu

Although the baseline scenario explored through this exercise is just one of several potential, hypothetical sequences of future events, it reflects evidence on barriers to water and sanitation service provision described elsewhere. A lack of demand for improved sanitation has been identified in several east African cities (Okurut & Charles, 2014), and high-density settlement patterns are recognized barriers to retrospective sewerage installation in urban informal settlements (Isunju, Schwartz, Schouten, Johnson, & Van Dijk, 2011). There was, however, little mention of some other barriers to urban sanitation upgrading, including lack of capital among petty landlords (Isunju et al., 2011).

The scenarios also raise several implications for water and sanitation planning across Kisumu County. All three groups foresaw groundwater as remaining part of the domestic water source mix ('mostly groundwater' or 'mixed') in at least some parts of the city until 2030 (Figure 5), as well as on-site sanitation (Figure 6). Therefore, the public health risks of groundwater use alongside intensifying use of on-site sanitation were not perceived as a transitory problem. This implies a longer-term need to find appropriate interventions to address this problem. These may include simplified sewerage systems that relax assumptions about required pipe diameters, gradients and depth to accommodate conditions in high-density informal settlements (Paterson, Mara, & Curtis, 2007); interventions such as household filters or chlorine dispensers at wellheads to treat groundwater, with accompanying education; or urban land-tenure reforms to enable sewerage installation.

It was also apparent from the groups' outputs that there was far greater uncertainty over the future of peri-urban areas such as Kanyakwar, compared to Kisumu's historic urban core (Figures 4–6). The historic urban core already has better access to basic services, and therefore a large-scale shift in access by 2030 is less likely here compared to peri-urban parts of the city, where service provision trajectories are more uncertain. This uncertainty reinforces calls for participatory planning approaches that are specifically targeted at such peri-urban areas (Allen, 2003).

Future research

An extended series of workshops would provide an opportunity to explore scenarios other than the continuation of current trends and policies, such as those already developed for Kenya under different scenarios for political and economic reform (Institute of Economic Affairs & Society for International Development, 2000), of which a more pessimistic scenario envisages ethnic conflict, social fragmentation, and unrest. Some participants also noted the need to apply such scenario planning to the small towns and hinterland around Kisumu, rather than the city itself. This was seen as particularly important because of rapid road-building and housing development, often Chinese-led, as one of the principal bilateral donors in Kenya (Benazeraf, 2014), and would require recruitment of a panel with specialist knowledge of such small towns.

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