Research article

# Exploring geographical variations and inequalities in access to improved water and sanitation in Ethiopia: mapping and spatial analysis

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## ABSTRACT

Ensuring access to improved water and sanitation remains a public health challenge in Ethiopia. Exploring access to improved drinking-water supply and sanitation will help to track the progress towards achieving the Sustainable Development Goals. The aim of this study was to explore geographical variations and inequalities in access to improved drinking water and sanitation in Ethiopia. A total of 16,650 households from 643 enumeration areas of the recent Ethiopian Demographic and Health Survey 2016 data were extracted and included in the analysis. World Health Organization recommended definitions were used to measure indicators of improved drinking water and sanitation at enumeration areas. SaTScan™ software was used for spatial analysis using enumeration areas as centers for exploring geographical variations of improved water and sanitation. Absolute and relative inequalities were used to quantify regional inequalities in access to improved water and sanitation. Nationwide access to improved drinking water and sanitation in Ethiopia was 49.6% (95% CI: 48.4–50.7) and 6.3% (5.8–6.8), respectively, with large variations between and within regions (using the categories and definitions that were in effect for monitoring coverage in 2016). Access to improved drinking water ranged from 28.5% in Somali Region to 95.3% in Addis Ababa city whereas access to improved sanitation ranged from 1.7% in Amhara Region to 24% in Dire Dawa city. Households lacking access to improved water and sanitation were clustered in northern (Amhara Region) and southern (Southern Nations, Nationalities, and Peoples' Region) parts of Ethiopia. Most enumeration areas had very low level of access to improved drinking water and/or sanitation. This analysis demonstrated the existence of geographical variations and inequalities in access to improved drinking water and sanitation in Ethiopia. Therefore strategies to improve access for safe drinking water and sanitation should consider geographical variations and inequalities at a subnational scale.

## 1. Introduction

Although there has been substantial progress in increasing access to safe drinking water and basic sanitation services worldwide and in Ethiopia, ensuring access to safe drinking water and basic sanitation remains a challenge (World Bank Group, 2017; World Health Organization & UNICEF, 2017).

Access to safe water and sanitation is crucial to support Ethiopia's ambitious development agenda. Evidence showed that inadequate water and sanitation are associated with considerable economic costs as well as increased risk of diarrheal diseases. There are differences in illness reduction according to the level of service achieved in improvements in access to water and sanitation services but the average level of diarrheal

disease reduction from the use of improved drinking water and access to improved sanitation facilities is 32% and 28%, respectively (Wolf et al., 2014).

The Member States of the United Nations set goals and designed strategies to ensure universal access to different services by the year 2030 (Bartram et al., 2018). The goals are for equitable and sustainable access to all types of services including safe water and improved sanitation at every level: from planetary biosphere to local community (Morton et al., 2017).

Geographical inequalities for different health services become a challenge for policy makers and implementers in both developed and developing countries of the world (Padilla et al., 2016). In 2017, it was reported that there are inequalities of drinking water and sanitation

services between countries and contexts. For instance, the coverage of safely managed drinking water services was ranged from just 7% in Uganda to >99% in 80 countries in 2017. Only 45% of the global population (3.4 billion people) used safely managed sanitation services, of which two thirds lived in urban areas in 2017 (UNICEF, 2019).

Access to improved water and sanitation inequalities may be linked with different parameters that include socio-economic status of the population and their geographical locations. Progress on equitable water, sanitation and hygiene has been driven by several factors which comprises of political commitment and attention that are often responding to wider economic or demographic trends and actions of households (Mason and Mosello, 2017). Exploring geographic variations and inequalities in access to improved drinking-water and sanitation will help to track progress towards the Sustainable Development Goals (SDGs). This information will help policy-makers and planners to give emphasis and strategically allocate scarce resources to achieve the SDGs. Hence, this study aimed to explore the absolute and relative inequalities in access to improved water and sanitation services in regions of the country and identify localities with low level of access by spatial analysis using the 2016 Ethiopian Demographic and Health Survey (EDHS) data.

## 2. Methods

### 2.1. Study design and setting

This study is a secondary data analysis using the EDHS 2016 dataset. EDHS was implemented by the Ethiopia Central Statistical Agency (CSA) with other partner agencies and ministries.

The sample selection procedure for the EDHS 2016 was designed to provide population and health indicators which are representative at both the national (urban and rural) and regional levels. The 2007 Population and Housing Census, conducted by the CSA, provided the sampling frame from which the EDHS 2016 sample was drawn. Ethiopia is composed of nine Regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations, Nationalities and Peoples (SNNP), Gambella and Harari, and two Administrative States (Addis Ababa City administration and Dire Dawa city council)). Regions in Ethiopia are successively divided into zones, districts, and kebeles, the lowest administrative unit in the government. During the 2007 census, each kebele was subdivided into enumeration areas (EAs) for implementation of the census. The EDHS 2016 sample was selected using a stratified, two-stage cluster sampling using EAs as the sampling units for the first stage. The sample included 643 EAs; 202 in urban areas and 441 in rural areas. Households comprised the second stage of sampling. A complete listing of households was carried out in each of the 643 selected EAs, and all households in all selected EAs were interviewed in the survey. The detailed methodology for sample selection and data collection is described in the EDHS 2016 report (Central Statistical Agency - CSA/Ethiopia & ICF, 2017).

### 2.2. Data measurement

The outcome variables were access to improved drinking water and sanitation, as defined by the Demographic and Health Survey (DHS) survey form 7 (DHS, 2015). Data from 16,650 households in 643 EAs were collected to determine the geographical variations and inequalities in access to the services. The number of households in a selected EA ranged from 5 to 29. In the DHS, access to improved drinking water source and sanitation services of a household were measured based on World Health Organization (WHO) definitions for the Millennium Development Goals (WHO/UNICEF, 2010). Improved drinking water sources include piped water on premises such as piped household water connection located inside the user's dwelling, plot or yard, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection. Unimproved drinking water sources include unprotected dug wells, unprotected springs, carts with small

tank/drum, tanker trucks, surface water (river, dam, lake, pond, stream, canal, irrigation channels) and bottled water. Improved sanitation facilities are those used by only one family and can include toilets connected to sewers or septic systems, water-based toilets that flush into pits, simple pit latrines with slabs, and ventilated improved pit latrines. Unimproved sanitation facilities include those shared by more than one household, flush/pour flush to elsewhere in the environment without proper waste water treatment, the use of buckets, hanging latrines, or pit latrines without slab coverings and open defecation (WHO/UNICEF, 2010). This study included the element of time to access, similar to the modification made for access to a basic water service in the revised definitions of access and coverage used for the Sustainable Development Goals. For this study, access to improved water also required a round trip travel time to/from source, including water collection, that was less than or equal to 30 min.

### 2.3. Data analysis

Data analysis was done using **Stata** version 14 software (StataCorp, 2015). The proportion of households with access to improved water and sanitation for each of the selected EAs and regions (with 95% confidence interval) was calculated by taking into account the complex survey sampling design, including stratification, cluster sampling and sample weights.

#### 2.3.1. Inequality analysis

The World Health Organization's recommended summary measures of inequality (the mean difference from mean and the weighted index of disparity) which were used in previous similar study were used to quantify the levels of inequalities between EAs and between regions (Afifah et al., 2018; Organization, 2013). Within each region, the mean difference from mean and the weighted index of disparity were calculated to measure absolute and relative inequalities, respectively, between the EAs in that region. Absolute and relative measures are recommended and appropriate to measure subnational (regional) health service inequalities, especially with larger numbers of subnational regions; they have advantages over other types of summary measures such as variance and the Theil index (Speybroeck et al., 2012). The mean difference from mean shows the average absolute difference between each EA and the regional average, which is calculated as the weighted sum of absolute differences between the EAs estimates and the region average. The weighted index of disparity is a relative measure of inequality that shows the average relative difference between each EA and the region average which is calculated as the weighted sum of absolute differences, divided by the region average. The formulas of mean difference from mean and the weighted index of disparity have been described in detail and published elsewhere (Afifah et al., 2018).

Quartiles were also used to measure the disparity of access to improved water supply and sanitation between EAs and regions.

#### 2.3.2. Spatial analysis

Spatial scan statistical analysis was used to identify statistically significant enumeration areas with low improved drinking water and sanitation access using SaTScan version 9.4 software (Kulldorff, 2015). Unlike other spatial statistical methods, the spatial scan statistical method has higher power in detecting local clusters and it is widely recommended for exploring localized clusters with health outcomes (Song and Kulldorff, 2003). Households without access to improved drinking water and sanitation were counted in each enumeration area and taken as cases, combined with total number of households as population in each EA to fit the discrete Poisson model. Then, Poisson data were analyzed with the purely spatial scan statistics to identify localized clusters with low improved drinking water and sanitation access. This spatial statistical analysis method employs the creation of a circular window that scans the entire study area to detect statistically significant localized clusters with low improved water and sanitation access. The

default maximum spatial cluster size of <50% of the population was used, as an upper limit, which allowed both small and large clusters to be detected and ignore clusters that contained more than the maximum limit. A Likelihood Ratio test statistic was used to determine if the number of observed households without improved drinking water and sanitation within the potential cluster was significantly higher than expected or not. The circle with the maximum likelihood ratio and containing more observed households without access to improved drinking water and sanitation than expected is identified as the most likely cluster that is least likely to have occurred by chance (Kulldorff, 1997). A Monte Carlo simulation with 999 runs was used to estimate the p-value, by comparing the rank of the maximum likelihood from the real dataset with the maximum likelihoods from the random datasets. A significance level of alpha <0.05 was used. The most likely and secondary clusters with low improved drinking water and sanitation access were identified based on their likelihood ratio test result and the p-value for this result.

## 3. Results

### 3.1. Households accessed to improved drinking water and sanitation services

At national level, households who had access to improved drinking water sources were 49.6% (95% CI: 48.4–50.7) with significant differences between regions within the country. Addis Ababa city administration had the highest proportion of households with access to improved water (95.3%, 95% CI: 94.1–96.2), while Somali Region had the lowest proportion of households with improved water (28.5%, 95% CI: 25.9–31.3). In seven (out of nine) regions and both of the two city administrations (Addis Ababa and Dire Dawa), more than 50% of the households had access to an improved water source (Table 1).

Although a very small proportion of households had access to improved sanitation facilities (now called "basic sanitation") across all regions and at national level, still there is great variation between regions. Comparing the regions, the highest proportion of households that had access to improved sanitation services were found in Dire Dawa city administration (24.0 %, 95% CI: 21.5–26.8) followed by Addis Ababa city (22.7%, 95% CI: 20.5–24.9), It is typical for urban areas to have higher access to sanitation than rural areas. The smallest proportion of households with access to improved sanitation services was found in Benishangul Gumuz region (1.8%, 95% CI: 1.2–2.8) followed by Amhara region (1.7%, 95% CI: 1.2–2.5). Households in Somali and Harari regions had the highest levels of access outside of the the two city administrations (Table 1).

### 3.2. Improved drinking water and sanitation access inequalities

The greatest relative inequalities of access to improved water source was observed in Somali region (85.2%) followed by Afar Region (82.4%).

On the other hand, the low disparities using relative inequalities as indicator were observed in Addis Ababa city administration (0.05%) and Gambela Region (27.0%). Cities by definition have more infrastructure, which could reduce the relative inequalities in access to improved water sources. This assumption was in line with the observed minimal level (0.05%) relative inequalities among enumeration areas in Addis Ababa., however, the relative inequality was larger in Dire Dawa (33.6%). In all cases except Addis Ababa, the relative inequalities were found to be greater than the absolute inequalities (Table 2).

The highest percent of inequalities in access to improved sanitation among enumeration areas was found in SNNP Region (88.5%) followed by Tigray region (85%). The lowest inequality between enumeration areas of each region was found in Somali Region (1.6%). Inequality between enumeration areas of Addis Ababa city administration was found to be substantially higher (74.6%) than other regions except the two previously described regions (SNNP and Tigray). The inequality in access to improved sanitation service in Dire Dawa city administration was also found to be substantial, at 61.0% (Table 2).

The quartile and spatial distribution of households that had access to improved water sources in each enumeration area, by region, are shown in Figures 1 and 2, respectively. More than 50% of the households in the enumeration areas in Afar and Somali Regions that had access to improved drinking water sources were found in the poorest quartile (1st quartile). On the other hand, 82.1% of the households of the enumeration areas in Addis Ababa city administration were found in the wealthiest quartile (4th quartile). This indicated that the majority of the households in each enumeration area of Addis Ababa had access to improved water sources more than the average value of the region. In both Dire Dawa city and Harari Region, 50 % of the households of the enumeration areas that had access to improved water sources were found in the 4th quartile.

The quartile and spatial distribution of households that had access to improved sanitation in each enumeration area, by region, is depicted in Figures 3 and 4 respectively. Addis Ababa and Dire Dawa city administrations had similar access to improved sanitation in which more than 50% of the households of the enumeration areas were found in the 4th quartile. Households of the enumeration areas in Amhara (76.1%), Benishangul Gumuz (70.0%), Afar (67.9%) and Gambela (60.0%) regions that had access to improved sanitation were found in the 1st quartile. This showed that more than 60% of the households in each enumeration area had less access to improved sanitation than the average access of the respective regions.

### 3.3. Spatial distribution of areas with very low access to improved water and sanitation services

The most likely cluster with low improved drinking water source was comprised of 11 enumeration areas in Somali Region (Likelihood Ratio (LLR) = .118.86, p-value<0.05). The spatial analysis also identified 16 significantly secondary clusters which comprised 127 enumeration areas

**Table 1.** Proportion of households with access to improved drinking water and sanitation by regions in Ethiopia, 2016.

| Region | Access to improved drinking water (95% CI) | Access to improved sanitation (95% CI) | Numbers of enumeration areas |
|---|---|---|---|
| National | 49.6 (48.4–50.7) | 6.3 (5.8–6.8) | 643 |
| Addis Ababa | 95.3 (94.1–96.2) | 22.7 (20.5–24.9) | 56 |
| Afar | 41.0 (37.8–44.4) | 4.1 (3.0–5.7) | 53 |
| Amhara | 45.9 (43.5–48.2) | 1.7 (1.2–2.5) | 71 |
| Benishangul | 62.0 (59.1–64.7) | 1.8 (1.2–2.8) | 50 |
| Dire Dawa | 75.9 (73.1–78.5) | 24.0 (21.5–26.8) | 44 |
| Gambela | 74.5 (71.8–77.1) | 8.2 (6.6–10.2) | 50 |
| Harari | 73.7 (70.9–76.2) | 17.1 (15.0–19.5) | 44 |
| Oromia | 51.5 (49.2–53.8) | 5.6 (4.7–6.8) | 74 |
| SNNPR | 39.3 (37.1–41.6) | 8.0 (6.8–9.3) | 71 |
| Somali | 28.5 (25.9–31.3) | 12.3 (10.3–14.6) | 67 |
| Tigray | 57.3 (55.0–60.0) | 7.7 (6.5–9.1) | 63 |

**Table 2.** Improved drinking water and sanitation access inequality by regions in Ethiopia, 2016.

| Region | Access to improved drinking water | | Access to improved sanitation | | Numbers of enumeration areas |
|---|---|---|---|---|---|
| | Absolute inequality* | Relative inequality** | Absolute inequality* | Relative inequality** | Enumeration areas |
| Addis Ababa | 4.9 | 0.05 | 16.9 | 74.6 | 56 |
| Afar | 33.8 | 82.4 | 4.4 | 6.8 | 53 |
| Amhara | 27.7 | 60.4 | 2.6 | 34 | 71 |
| Benishangul | 22.6 | 36.5 | 2.6 | 30.8 | 50 |
| Dire Dawa | 25.5 | 33.6 | 14.6 | 61 | 44 |
| Gambela | 20.2 | 27 | 8.8 | 6.8 | 50 |
| Harari | 26.3 | 37.7 | 11.5 | 15.6 | 44 |
| Oromia | 27.7 | 53.7 | 7 | 20 | 74 |
| SNNPR | 26.6 | 67.6 | 7.1 | 88.5 | 71 |
| Somali | 24.3 | 85.2 | 12.5 | 1.6 | 67 |
| Tigray | 29 | 51 | 6.6 | 85 | 63 |

* Absolute inequality is measured by the Mean Difference from Mean.
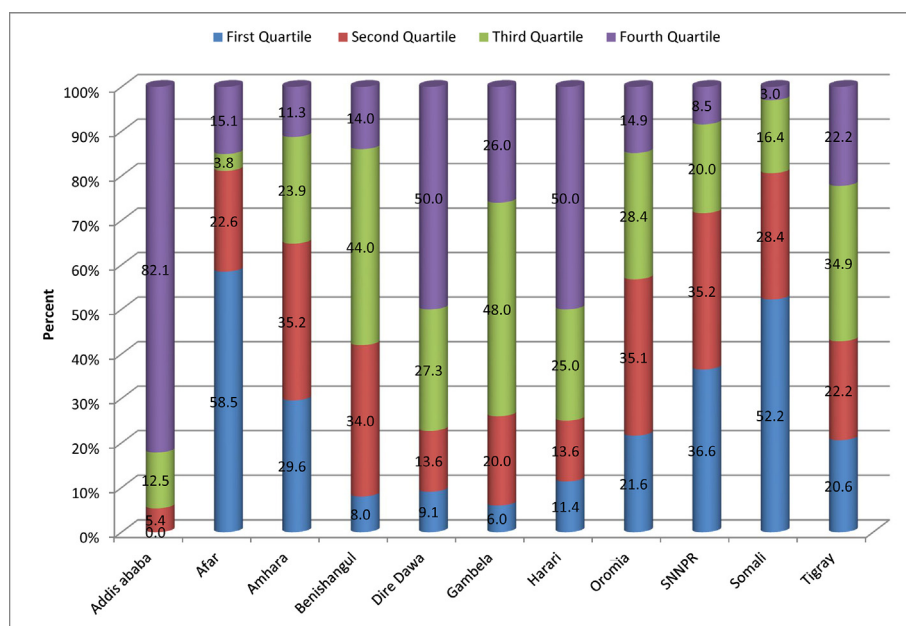** Relative inequality is measured by the Weighted Index of Disparity.



**Figure 1.** Enumeration areas with access to improved water sources in each region, by wealth quartile, Ethiopia, 2016.

with low access to improved sanitation (Table 3). Among the clusters included in the spatial analysis, the three clusters with lowest levels of improved drinking water access were located in Somali region, Oromia region and Amhara Regions (Figure 5).

### 3.4. Spatial distribution of areas with high proportion of open defecation

The most likely cluster with significantly low accessed to improved sanitation was located in Amhara region (LLR = 165.08, p-value<0.001) (Table 4). The spatial analysis showed that two secondary clusters with significantly low accessed to improved sanitation were also identified in Afar (LLR = 13.9, p-value<0.001) and SNNP regions (LLR = 9.97, p-value<0.01) (Figure 6).

### 4. Discussion

It is already evident that safely managed drinking water and sanitation services coverage varies considerably between countries (World Health Organization & UNICEF, 2017). In Ethiopia, there is limited information on geographical variations and inequalities in

access to improved drinking water and sanitation services at a national level whilst a total lack at the subnational level (regional level). This is the first attempt to systematically map and analyze geographical inequalities in access to improved drinking water and sanitation coverage within the country at the regional level using spatial analysis. The study has generated a new resource for researchers, country stakeholders, policy makers, and donors by exploring spatial heterogeneity and geographical inequalities for WASH sectors to achieve and measure the targets of sustainable development goals of universal access to safely managed drinking water and sanitation services.

In Ethiopia, time taken to fetch water was not considered while measuring access to improved water during the Millennium Development Goal period 1990–2015. This study revealed that there is a clear discrepancy of having access to improved water sources with coverage in the country with considering fetching time of less than 30 min (49.6%) as well as without considering fetching time (65%). Distance is an important determinant of the quantity of water brought to the household, which in turn had an effect on infectious diseases, and other health problems associated with water carriage. Systematic review and meta-
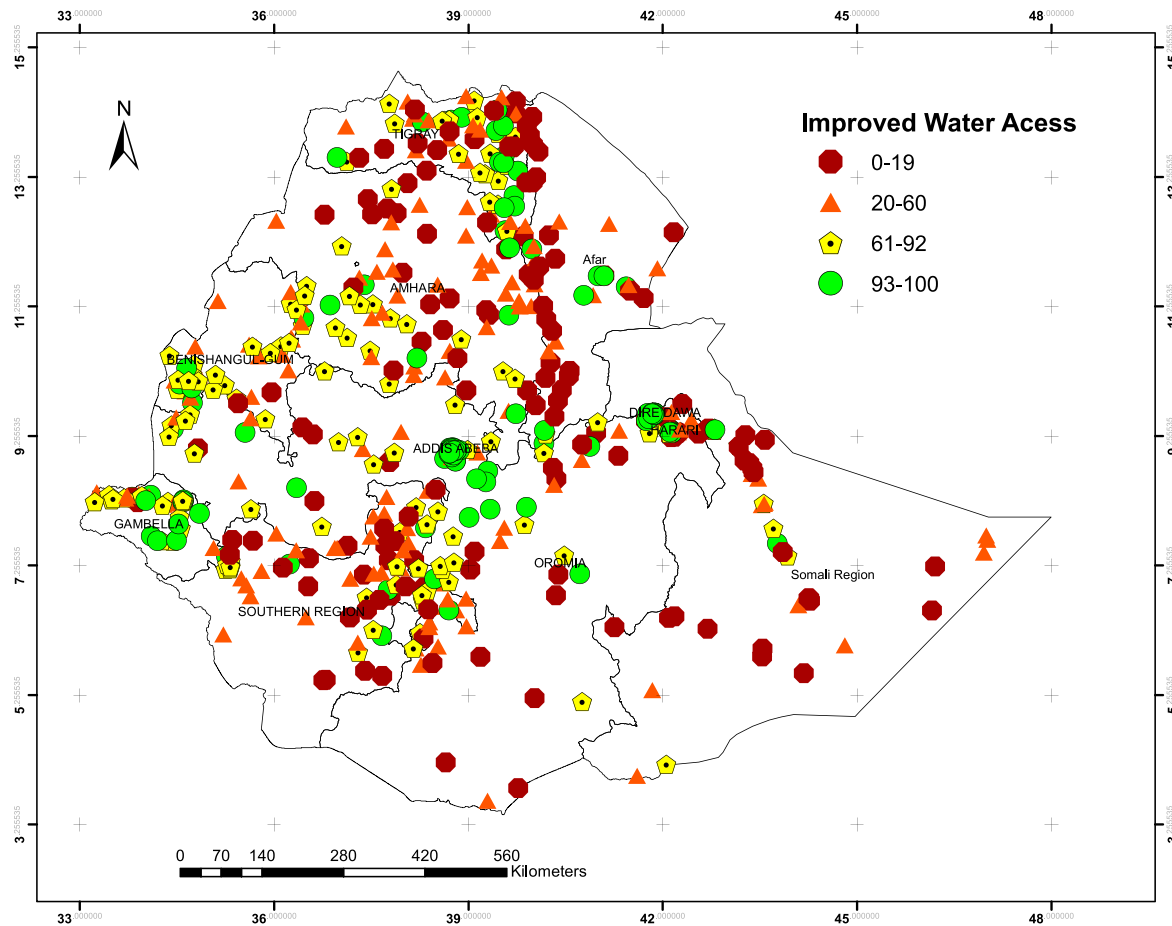
**Figure 2.** Spaital distribution of access to improved water sources in enumeration areas Ethiopia, 2016
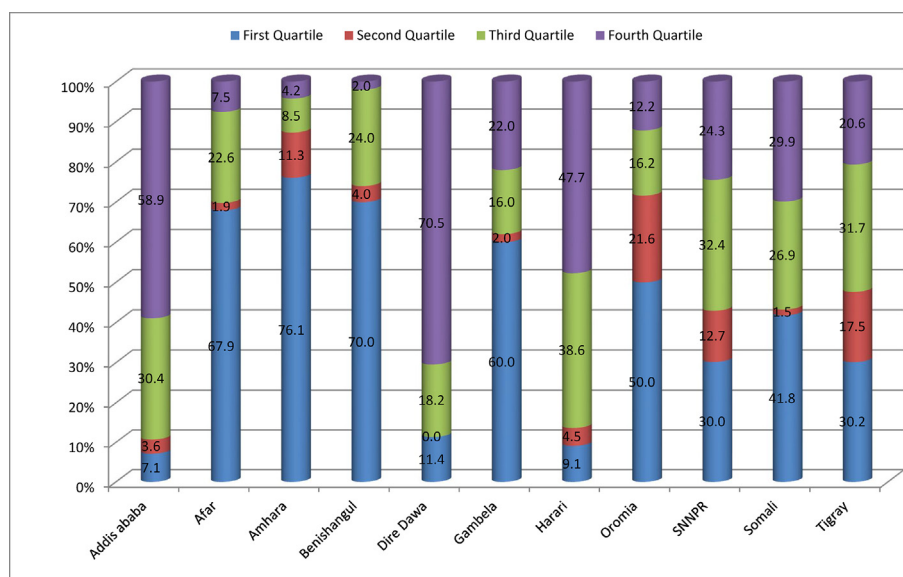


**Figure 3.** Enumeration areas with access to improved sanitation in each region and administrative state, by wealth quartile, Ethiopia, 2016.
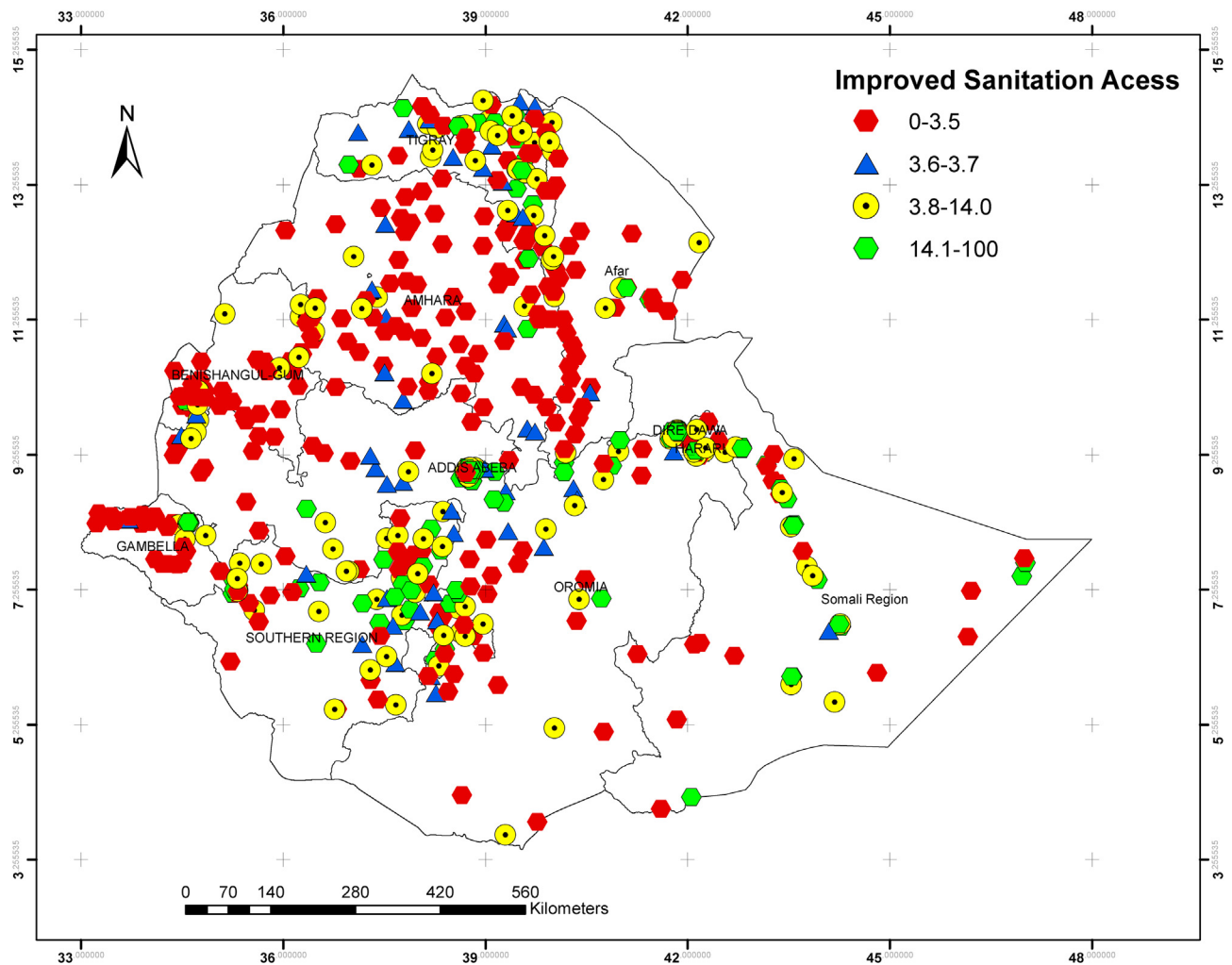
**Figure 4.** Spaital distribtuion of access to improved sanitation in enumeration areas Ethiopia, 2016.

**Table 3.** Most likely and secondary clusters with low improved drinking water access areas, Ethiopia, 2016.

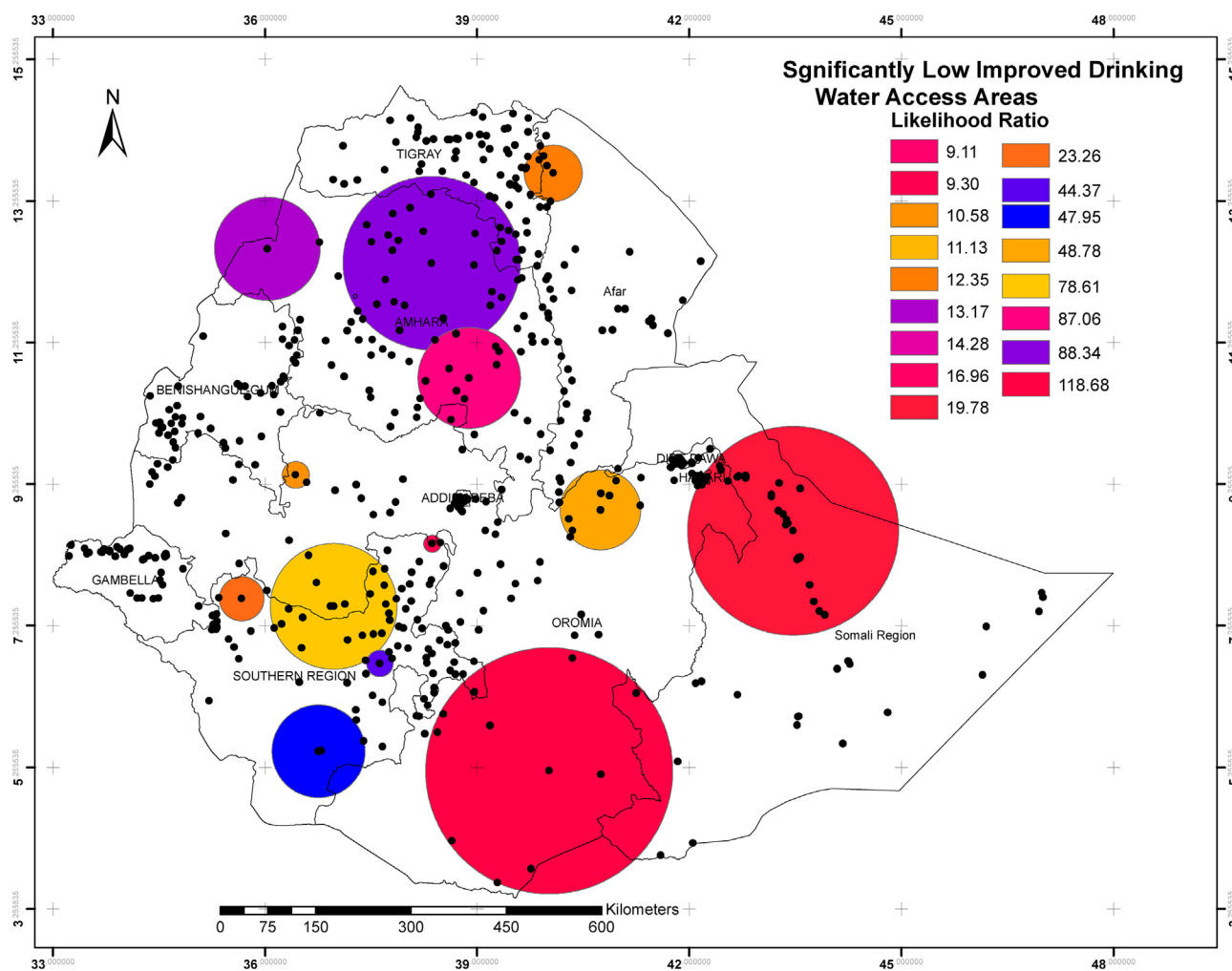| Cluster | Latitude | Longitude | Radius | Number of EAs in the cluster | LLR* | Observed cases | Expected cases | RR | P-value |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.203234 | 40.01973 | 193.4 | 11 | 118.68 | 76 | 294.64 | 0.25 | <0.001 |
| 2 | 12.37694 | 38.35798 | 136.2 | 31 | 88.33 | 441 | 765.47 | 0.55 | <0.001 |
| 3 | 10.75389 | 38.88843 | 79.2 | 11 | 87.06 | 103 | 296.63 | 0.34 | <0.001 |
| 4 | 7.527086 | 36.97095 | 98.8 | 21 | 78.61 | 325 | 595.75 | 0.53 | <0.001 |
| 5 | 8.888553 | 40.74457 | 62.7 | 7 | 48.78 | 145 | 295.64 | 0.48 | <0.001 |
| 6 | 5.480089 | 36.75733 | 72.9 | 3 | 47.95 | 3 | 59.72 | 0.05 | <0.001 |
| 7 | 6.720108 | 37.62488 | 20.7 | 2 | 44.37 | 2 | 52.76 | 0.04 | <0.001 |
| 8 | 7.634558 | 35.67017 | 34.9 | 2 | 23.26 | 19 | 65.70 | 0.29 | <0.001 |
| 9 | 8.5956 | 43.4703 | 164.1 | 33 | 19.78 | 118 | 199.08 | 0.59 | <0.001 |
| 10 | 6.933492 | 38.02535 | 0.0 | 1 | 16.96 | 2 | 23.89 | 0.08 | <0.001 |
| 11 | 8.848275 | 37.77392 | 0.0 | 1 | 14.28 | 7 | 31.85 | 0.22 | <0.001 |
| 12 | 12.57909 | 36.03327 | 81.1 | 2 | 13.17 | 33 | 71.67 | 0.46 | <0.001 |
| 13 | 13.64635 | 40.07762 | 44.4 | 7 | 12.35 | 4 | 23.39 | 0.17 | <0.01 |
| 14 | 7.335742 | 38.159 | 0.0 | 1 | 11.13 | 6 | 25.88 | 0.23 | <0.01 |
| 15 | 9.384163 | 36.43563 | 21.1 | 2 | 10.58 | 14 | 38.82 | 0.36 | <0.05 |
| 16 | 8.411698 | 38.36604 | 13.5 | 2 | 9.30 | 33 | 64.20 | 0.51 | <0.05 |
| 17 | 11.54315 | 37.22078 | 0.0 | 1 | 9.11 | 12 | 33.35 | 0.36 | <0.05 |
| Total enumeration areas | | | | 138 | | | | | |

*LLR = Likelihood Ratio.

**Figure 5.** Most likely and secondary clusters with low access to improved water areas Ethiopia, 2016.

**Table 4.** Most likely and secondary clusters with low improved sanitation areas Ethiopia, 2016.

| Cluster | Latitude | Longitude | Radius | Number of EAs in the cluster | LLR* | P -value | Observed Cases | Expected Cases | RR |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.42079 | 37.16212 | 258.1711 | 90 | 165.08 | <0.001 | 43 | 257.73 | 0.13 |
| 2 | 9.727612 | 40.03752 | 103.4805 | 20 | 13.93 | <0.001 | 8 | 32.94 | 0.24 |
| 3 | 6.782497 | 35.63619 | 80.81438 | 17 | 9.97 | <0.01 | 3 | 18.27 | 0.16 |
| Total enumeration areas | | | | 127 | | | | | |

*LLR = Likelihood Ratio.

analysis and other studies revealed that people living far away from their improved water source has significant increase in illness risk in developing countries, like diarrheal diseases (Nygren et al., 2016; Pickering and Davis, 2012; Wang and Hunter, 2010), musculoskeletal disorders among women and children (Geere et al., 2018), perinatal and mental health problems, and violence against vulnerable people (Geere et al., 2018).

The study revealed that access to improved drinking water in Ethiopia is lower compared to the average global proportion. It is also lower than the other sub-Saharan countries where the access proportion has shown substantial progress between 2000 and 2017. Generally, there is continuous progress in accessing improved drinking water in all parts of the world except Oceania (UNICEF, 2019). This lower access for improved drinking water source for Ethiopia could be due to population growth and low socio-economic status of the country compared with other countries in the world. This socio-economical or wealth status variability as means

of access differences is supported with literature in that those with better wealth status would have better access to improved water sources compared with their counter parts (World Bank Group, 2017). The current study revealed the presence of a significant geographical inequality in access to improved drinking water between regions in the country. Access to improved drinking water was significantly lower in Afar, Amhara and SNNP Regions. Spatial analysis also confirmed that locations in these regions were identified with significantly low coverage in access to improved drinking water supply. Literature revealed that variations to access to improved drinking water sources can be affected by economic and human behavior (Armah et al., 2018). It could be similar for this analysis in which residents in different regions and EAs possibly have different economic status and behaviors. Both governmental and non-governmental organizations should target the locations identified as significantly lower in access as a primary target for interventions to satisfy this basic need.
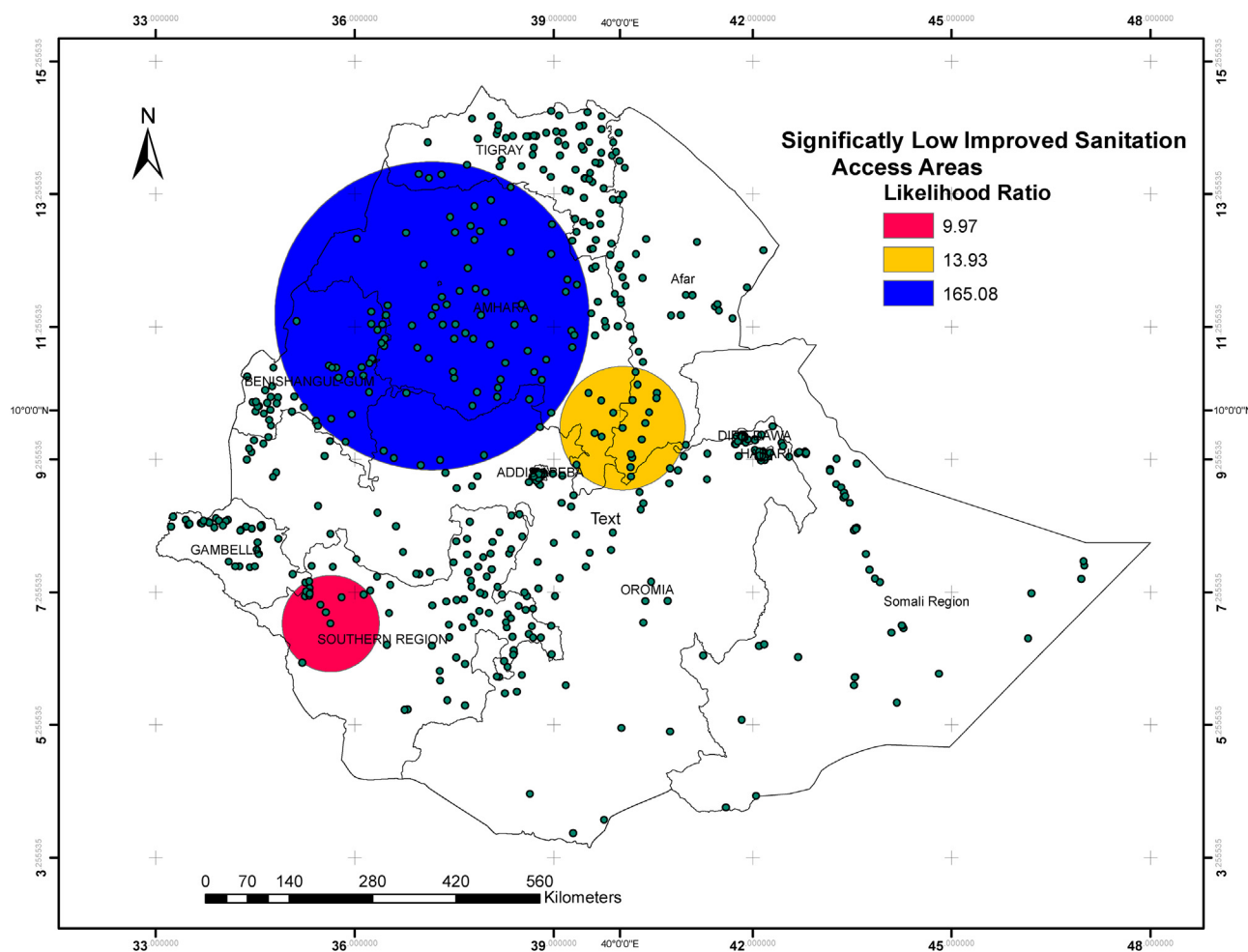
**Figure 6.** Most likely and secondary clusters with low access to improved sanitation areas Ethiopia, 2016.

The study also revealed that there was a substantial geographical inequality in access to improved sanitation in the country. There are regions with lowest coverage of access to improved sanitation (Amhara, Benshagul-Gumuz) and these regions also had high inequalities within enumeration areas. Although the two city administrations (Addis Ababa and Dire Dawa) had the highest overall coverage of access to improved sanitation, there were substantial inequalities within enumeration areas. This substantial difference in accessing improved sanitation among regions and EAs can result from an urban environment that has a higher average wealth status than rural areas. Compositional factors that relate to socio-cultural, lifestyle and behavioral characteristics of the residents can also cause this variation. It is true in many African countries where urban city and compositional factors significantly contribute for the occurrence of inequalities in accessing improved sanitation among countries (Armah et al., 2018). Understanding the patterns of inequality is an important first step in devising appropriate strategies to tackle it.

The inequality of Addis Ababa city in access to improved drinking water within EAs was low while the inequality in access to improved sanitation within EAs was higher. The possible explanations for this high inequality in accessing improved sanitation could be seen from different perspectives. Primarily, the internal migrants from the surrounding areas of the city are high. This leads to illegal house construction and sub-standard settlements that further causes overcrowding and slum areas. The presence of overcrowding and slum areas in a city is typical risk factors for not having access to improved sanitation services, which increase inequalities. Associated with this, the migrants from the rural parts of the country place less value for sanitation services due to the fact that they have less awareness of the benefits of improved sanitation,

which likely contributes for the occurrence of high inequalities among EAs. Furthermore, the population of the city may increase disproportionately at different localities, overburdening existing sanitation facilities in areas of high population growth without new infrastructure establishment. This is true for other African countries where the percentage of WASH service coverage has declined in urban settings because of rapid population growth without new infrastructure expansion (World Bank Group, 2017), even as there were increases in absolute numbers gaining access. The spatial scan statistical method also confirmed the presence of statistically significant spatial hotspots/cluster with low coverage to improved drinking water and sanitation. A total of 17 significant clusters which comprised 138 EAs with low coverage of drinking water were identified in the country. Significant clusters with low coverage of improved water were detected in Afar, Somali, Oromia, SNNP and Amhara Regions. The descriptive results also supported the above results in which most households (above 50%) in Afar and Somali Regions had low access to improved drinking water sources which had fallen in the first quartile compared to the national average. In Amhara, SNNP and Oromia Regions also showed that 20–30% of the households in the enumeration area had low access to improved drinking water. The recent survey conducted at population level also revealed that there is huge gap in distribution in access to improved drinking water (Central Statistical Agency of Ethiopia, 2017).

Ethiopia is one of the countries with low coverage of improved sanitation and with great disparity between regions. The highest coverage was observed in the two city administrations of Addis Ababa and Dire Daws. Most of households in the regions had no improved sanitation facilities. The spatial scan statistical method identified 127

enumeration areas with statistically significant spatial clusters of low coverage of improved sanitation. Most likely clusters were located in two regions (Amhara and Benishangul Gumuz Regions).

## 5. Conclusions

There are geographical variations and inequalities in access to improved drinking water and sanitation in Ethiopia. A high inequality in access to improved water supply is observed between enumeration areas in all regions and administrative states except in the capital city of Ethiopia, Addis Ababa. Higher inequality is also observed in access to improved sanitation in Addis Ababa city administration, SNNP, and Tigray regions. The spatial analysis revealed that the most likely cluster with low improved drinking water source was found in Somali Region, while the most likely cluster with low improved sanitation was found in Amhara Region. Therefore, in developing strategies to improve access for clean drinking water and sanitation should consider these geographical variations and inequalities with more emphasis given to the identified areas to support progress towards the Sustainable Development Goal of universal access by 2030.

## Declarations

### Author contribution statement

### Funding statement

### Competing interest statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

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