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ABSTRACT

BACKGROUND: The health effects of climate change have been found to be a global concern for the last 2 centuries. However, the effect of climate variability on diarrhoea among under-five-year-old children is perhaps undocumented or otherwise unknown. The aim of the present study was to determine the effect of climate variability on diarrhoea among children under 5 years of age.

METHODS: A community-based longitudinal study was conducted over 8 repeated visits from June 2016 to May 2018 at the Kersa Demographic Surveillance and Health Research Center. A total of 500 randomly selected households and their 48 improved water sources were included in the survey from 3 agro-ecological zones, the rural and urban areas of the study area. Data was collected on household characteristics, diarrhoea, WASH practices, water quality and quantity in households, and improved water sources. A structured pre-tested questionnaire, an observational check list and laboratory tests were used for data collection. The data was entered into Epi Data Version 3.01 and transferred to Stata Version 12 for analysis. Multilevel mixed-effect Poisson regression was used to determine the relationship between predictors and outcome variables. A *P*-value of less than .05 was the cut-off point for statistically significant.

RESULTS: The prevalence of diarrhoea in 2 weeks among children under 5 years of age was 17.2% (95% CI: 15.8-19.71). Rainfall, *E. coli* contamination of drinking water at the source and in the home, 20 L of water consumption per capita per day, sharing water sources with animals and home water treatment by residents of the mid- and lowlands were all predictors of diarrhoea. The space-time scan statistic confirmed that child diarrhoea had random variation in both space and time.

CONCLUSION: Climate variability has influenced the prevalence of diarrhoea among under-five-year-old children. Climate-resilient measures should be taken to reduce the burden of diarrhoea in the community.

KEYWORDS: Climate variability, diarrhoea, Under five children, Ethiopia

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Introduction

Globally diarrhoea is a leading cause of morbidity and mortality among children under the age of 5 especially in low- and middle-income countries.[1,2] The environment is responsible for the diarrhoeal disease burden, including risks associated with inadequate water, a lack of sanitation and poor hygiene. Annually, diarrhoea disease causes 842 000 deaths in all age groups and 361 000 deaths in children under 5 years of age due to inadequate water sanitation and hygiene in low and middle-income countries.[3]

A review of the literature, which includes 61 studies on diarrhoea, morbidity and mortality, shows that mortality from diarrhoea has decreased substantially, although morbidity has remained high in recent decades. The estimated median number of annual deaths from diarrhoea fell from 4.6 million in 1982 to 3.0 million in 1992 and 2.5 million in 2000, despite world population growth.[4] Studies indicate that diarrhoea and enteric diseases show evidence of significant seasonal fluctuations among young children.[5]

Evidence of water contamination has been documented after heavy rains for cryptosporidium, giardia and *E. coli*.[6] It may be due to the fact that during rainy seasons, due to flooding, drinking water sources are destroyed and contaminated with organic waste. On the other hand, water shortages in developing countries have been associated with increased outbreaks of diarrhoeal diseases that are likely attributed to improper hygiene.[7] The cross-sectional studies conducted in Ethiopia found that diarrhoea is strongly associated with water quality and quantity, as well as sanitation, including personal hygiene.[8-11]

Climate-sensitive diseases such as vector-borne, water-borne and water-washed diseases are widely spread in Ethiopia. Diarrhoea diseases are waterborne diseases in which the presence of faecal matter injects pathogenic microorganisms into drinking water and causes illness when ingested. Diarrhoea is widespread among children, contributing to a frequency of 3 to 5 episodes per child annually.[12] A study conducted in Ethiopia indicated that the overall mean prevalence of diarrhoea was 22% ± 7.5% (SD).[13] In addition, an improved sanitation and water supply showed a borderline association with diarrhoea, but not significant. However, the sex of a child, the status of vaccination, parental education and ecology were found to be determinants.[13] However, the link between climate-sensitive diseases and climate variability is not well documented in the Ethiopian context. Therefore, the present study aimed to determine the relative contributions of behavioural, environmental, socioeconomic and technical factors to changes in the prevalence of diarrhoea among under-five-year-old children during short-term variations in meteorological variables.

Materials and Methodology

Setting and study period

This study was carried out in Kersa district, where there is a well-established demographic surveillance and health research site (KDS-HRC). KDS-HRC is located in Kersa district in the eastern part of Ethiopia between *41040″0′* and *41057″30′* easting and *09015″15′* and *09029″ 15′* northing; and the elevation ranges from 1400 to 3200 m above sea level.

In the district, there are 35 rural sub districts (called 'kebeles') and 3 small towns. According to the district administration, 2 of the 38 sub districts are lowland, 22 are temperate, 7 are a mix of lowland and temperate, and 7 are highland, accounting for 2.8%, 60.2%, 17.1% and 20% of the district population, respectively.[14]

According to Ethiopian government censuses in 2007, the district has a total population of 172 626 people, out of which 6.87% are urban dwellers.[15] With an estimated area of 463.75 square kilometers, Kersa has an estimated population density of 372.24 people per square kilometer. The main sources of water supply in the sub-districts are improved water sources (springs and wells), but in the towns and nearby sub-districts there is tap water supply.[14] This study was conducted from June 2016 to May 2019. Each round of the survey was conducted within 7 to 10 days.

Study design and population

A community-based longitudinal panel survey was conducted to measure changes in the prevalence of diarrhoea among under-five-year-old children over time and under varying meteorological conditions (temperature and precipitation). All households with children under 5 years of age and an improved water source in the Kersa district were the source population. All households with children under 5 years of age, all households that use an improved water source and an improved water source at the KDS-HRC site were included in the study population. If an appropriate respondent was not present in the household during data collection like the person responsible for water collection, likely to be the mother or girl, age >15 years or respondent refused to provide informed consent were excluded from the study and the reasons will be clearly recorded.

Selection of study sites (clusters)

The study site was identified based on the presence of well-established demographic surveillance and health research KDS-HRC sites, the availability of 3 agro-ecological zones (lowland, midland and highland), and urban and rural areas. First, we identified improved water sources in the study area, and households within a radius of 1 km of the improved water sources were the study clusters. Consequently, the study groups were first stratified into urban and rural locations, and the rural sites were further stratified into 3 agro-ecological zones (high, middle and lowland). Then, 12 groups were randomly selected from each of the 3 rural agro-ecological strata and the remaining 12 from urban kebeles (Figure 2). All kebeles were included in the sampling process.

The study groups were based on a focal improved water supply; eligible households were defined as households located within a radius of 1 km of the focal water supply and included households that had used the focal water supply at least once within the past year. An improved drinking water source as defined by WHO is one that, by the nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter. It includes piped water to the home, piped water to the yard/plot, public taps or standpipes, tube wells or well bores, protected dug wells, protected springs and rainwater collection.

Selection of existing interventions/practices

In this longitudinal study, existing potential climate resilient interventions/practices such as household water treatment, safe storage, hand washing and WASH education were included.

Sampling procedure/technique

Three rural agro-ecological zones and an urban area were selected based on the availability of improved water sources. A baseline survey was conducted at time zero. Information was collected on the water source, socioeconomic indicators, distance to focal water sources and distances to alternative water sources. A unique identifier was given to each water source. If a household uses, more than 1 water source, all the sources' unique IDs were registered and linked for later analysis. First, a focal improved water source was identified; and then households within a radius of 1 km surrounding the improved water source were mapped. Second, a household census was conducted to identify eligible households that used the improved water source during the past year. Finally, systematic random sampling was used to select households within the selected clusters.

Data collection methods and procedures

Set up of study sites. The community and community leaders were involved in selecting the study sites. Initial site visits were held to confirm the suitability of the study sites and to engage the community and community leaders in the study. Discussions with the community, community leaders and water supply managers (community or utility) were used to map the extent to which the community relies on the focal improved water source and alternative water supplies. Discussions were also used to develop an understanding of seasonal patterns within the community that can influence the design of the study or results, such as seasonal work or migration to work, problems with the water supply experienced in recent years, the age of the water supply (s) and community or religious festivals.

Research schedule and visit

The research team worked closely with community leaders, health extension workers and water managers to keep in contact with the research team to notify them of changes in meteorological conditions. Historic meteorological data, local knowledge from set-up visits, and seasonal forecasts were used to develop a proposed visit schedule for the study sites. Consequently, visits were carried out during the end of the dry season when water scarcity is expected, the beginning of the rainy season, times when peak rainfall intensities are expected, and periods when higher rates of diarrhoea are reported.This community-based longitudinal panel survey had 8 repeated visits during the 2-year study period. Before the research visits began, the data collection instruments were developed, piloted and refined. Visits were carried out in 4 seasons (spring, autumn, winter and summer). These repeated measures allowed us to determine the variation among the seasons, and that each season had its own distinct metrological events. Based on local knowledge collected from community leaders, meteorological events within the seasons have not shown significant variation. However, visits were scheduled in the middle of each season, which helped to get representative data of the seasons. Furthermore, there were additional short-term visits from community leaders when the community was experiencing an event.

During the first visit (baseline), the team identified households that qualified for the study and conducted household surveys to collect data on demographic and socioeconomic information, household water sources and water handling practices, access and water quality, sanitation and hygiene facilities, housing conditions and diarrhoea within the community. Data were collected from each household, and the bacteriological and physicochemical quality of water samples were tested from all improved water sources as well as the participating households' water storage containers. Bacteriological analysis and physicochemical tests were performed using field test kits on site. The field test kits operate with batteries, as there is no electricity in rural areas. Meteorological data was obtained from the meteorological agency for the study period.

At each panel visit, the team conducted a sanitary risk assessment and collected data on water sources, water quality, sanitation facilities and household surveys with interviews and observations of water handling practices.

To minimize bias in behaviour in response to repeated visits, data collectors and supervisors were trained in repeated data collection techniques, and households were not informed of the timetable and visits in advance.

The survey instruments were designed to capture descriptive answers as to why behaviour and usage have changed and to enable interviewer investigation.

Data collectors and supervisors

There were 3 groups of data collectors. The first team conducted a sanitary risk assessment on water sources. Six data collectors had BSc holders in health and health-related fields were conducted water quality analysis and sanitary risk assessment. The third team conducted household interviews. Fifteen data collectors had diploma in health and health-related fields conducted a household interview. Two supervisors were BSc or higher holders in health and health-related fields, who had experience in supervision and could, speak the local language. Both data collectors and supervisors were trained in interviewing techniques, data recording, water quality analysis and sanitary surveys for 5 days. After the training, the pre-test was conducted in the neighbouring district. Then some amendments were made to the data collection instrument based on the results obtained from the pre-test.

Survey instruments

Combinations of quantitative and qualitative data collection are required to achieve the objectives. The survey instrument was adopted from the Multiple Indicator Cluster Survey (MICS), EDHS, UNICEF and WHO core questions and was first developed collectively in English, translated into the local language and pretested in the Haramaya district. The survey format was developed to allow the interviewer to reflect on responses from previous visits to ensure that changes in behaviour are identified and discussed.

Data quality control

To ensure quality, data collectors and supervisors were trained and the main focus of the training was on the study objectives and data collection procedures. To facilitate data collection and maintain context, the questionnaire was translated into the local language (Afan, Oromo). Additionally, the language skills of the data collectors were considered during the recruitment. Data collection instruments were tested in the nearby district and amended based on comments from the pre-test. In addition to these, the completeness, accuracy and consistency of the collected data were checked daily during data collection. Double data entry was used to validate the data.

Data processing and analysis

The collected data were checked for its completeness, entered into EpiData Version 3.01, and exported to Stata Version 12 for analysis. There were 8 waves of data collection in 2 years. Each of the data points in a year was represented by 2 weeks of data collection for a given season that can affect the prevalence of diarrhoea in the study area.

Descriptive statistics were used to describe the distribution of the study variables. Households with under-five children were included in the analysis. The prevalence of diarrhoea among children under 5 years of age was calculated for each season. The socioeconomic, environmental and behavioural factors associated with diarrhoea were multifaceted and at different levels. A multilevel mixed-effects Poisson regression analysis was used to take into account the level of these variables and to identify the predictors of diarrhoea among under-five-year-old children. Accordingly, explanatory variables at the household level were included in the first model. In the second model, the variables of the water source were included. In the final model, household and water source variables were included to identify predictors of diarrhoea among children under 5 years of age. A P value of less than .05 was used as a cut-off point for statistical significance.

Data from 8 round periods spanning June 2016 to May 2018 was used to identify pure spatial, spatiotemporal and pure temporal clusters of childhood diarrhoea. The logarithmic likelihood ratio (LLR) test was used to test the null hypothesis that the risk of disease inside the circular window is the same as outside the circular window. The circular window with the maximum likelihood was the most likely cluster (s), which is the least likely to have occurred by chance. A p-value was determined using a combination of approximations by comparing the rank of LLR of real datasets with a random simulated dataset using 999 replications of the Monte Carlo simulation. A P-value of $<.05$ was used to identify a group with a significant number of diarrhoea cases.

Ethical considerations

Ethical approval was obtained from the Institutional Health Research Ethics Review Committee of Haramaya University School of Health and Medical Sciences (IHRERC). Permission to collect data was obtained from the respective local administrative and health offices. The field team explained the purpose of the study to each prospective household, highlighting that participation is voluntary and that study participants can withdraw at any time. In Ethiopia, a person over 18 years of age can give their consent. However, if the study participant was a minor (under 15 years old), the consent was taken from the parents. In Ethiopian culture, a woman or a man can give their consent to the household. Therefore, written consent was obtained from the mother or caregiver in each household that was enrolled in the study.

Results

Background characteristics of the study participants at the baseline

A total of 595 children under the age of 5 years participated in the baseline survey of the longitudinal study. The majority of the study participants, 77% were from the rural area, while 23% were from the urban area. Regarding the educational status, 84% of the mothers/caregivers and 85.54% of housewives were illiterate. About 41.94% of the age of mothers and caregivers were between 25 and 34 years old. In addition, 51.6% of the households had a family size of 4 to 6 (Table 1).

Environmental and behavioural characteristics within the 2-year study period

Data on diarrhoea was collected from households that had at least 1 child under-five years of age. In 8 seasons, 3304 households visited repeatedly, 1083 (67.3%) of the water samples from the storage containers of households were positive for *E. coli*. Tap water was the sources of water supply for 51.6% of households. Three-quarters of the households, 2455 (74.3%), had water consumption of less than 20 L per capita per day. Of the 3304 households that, 295 (8.36 %) had treated their drinking water at home. One in five (20.14%) of the households shared water sources with domestic animals (Table 2).

Seasonal variability of climate parameters and diarrhoea

In all, 2 waves of diarrhoea per wave were assessed among under-five-year-old children in the 2-year period. In 8 seasons, 5093 children repeatedly visited, 878 (17.23%) diarrhoea cases were reported, which is equivalent to 17.23 cases per 100 populations under 5 years of age in the 2-year period. The trend shows that there was a significant variation in diarrhoea cases in children between seasons.

Table 1. Socio-demographic and social economic characteristics of study participants in Kersa Demographic Surveillance and Research Center, Eastern Ethiopia, August 2016.

CHARACTERISTICS	FREQUENCY	PERCENT
Age of the children (months)		
0-11	66	11.09
12-23	80	13.44
24-35	111	18.65
36-47	134	22.52
48-59	204	34.28
Number of under-five children in the Household		
One	220	36.97
Two	273	45.88
Three	102	17.14
Is there separate kitchen?		
Yes	432	72.60
No	163	27.39
Age of the mother/caregiver(years)		
<25	62	10.42
25-34	293	49.24
35-44	196	32.94
$\geqslant 45$	44	7.39
Occupation of the respondent		
Merchant	22	3.69
Farmer	49	8.23
Housewives	509	85.54
Other	15	2.52
Educational status of the mother/caregiver		
Literate	95	16
Illiterate	497	84
Wealth index		
Poor	193	32.4
Middle	205	34.4
Better off	197	33.2
Residence		
Urban	137	23
Rural	458	77
Family size		
1-3	43	7.2
4-6	307	51.6
7-12	245	41.2

Table 2. Environmental and behavioural characteristics of study participants, Kersa Demographic Surveillance and Research Center, Eastern Ethiopia, August 2016 – May 2018.

CHARACTERISTICS		FREQUENCY	PERCENT
Escherichia coli count	<1	1083	32.7
	1-10	405	12.26
	11-100	1043	31.57
	>100	773	23.40
Type water source	Public and private tap	1706	51.63
	Protected well and spring	1, 598	48.37
Basic access to drinking water	$\geqslant 20$ L	849	25.70
	<20 L	2455	74.30
Waste disposal	Proper	1624	49.15
	Improper	1680	50.85
Child stool disposal	Proper	1535	46.46
	Improper	1769	53.54
Time spent on water collection	$\leqslant 15$ min	711	21.52
	16-30 min	440	13.32
	minutes	1112	33.66
	>60 min	1041	31.51
Water transfer	Pouring	3169	96.15
	Dipping	127	3.85
Do you pay for water	Yes	1307	39.56
	No	1997	60.44
Household water treatment	Yes	295	8.36
	No	3233	91.64
Open defecation	Yes	2021	61.17
	No	1260	38.14
	Do not knows	23	0.7
WASH education	Received	957	28.96
	Not received	2347	71.04
Animals use water source	No	2637	79.86
	Yes	665	20.14
Placement of drinking water	Proper place	624	18.89
	On the ground	2680	81.11
Agro- Ecological zone	High land	825	25.35
	Mid land	1578	48.48
	Low land	852	26.18

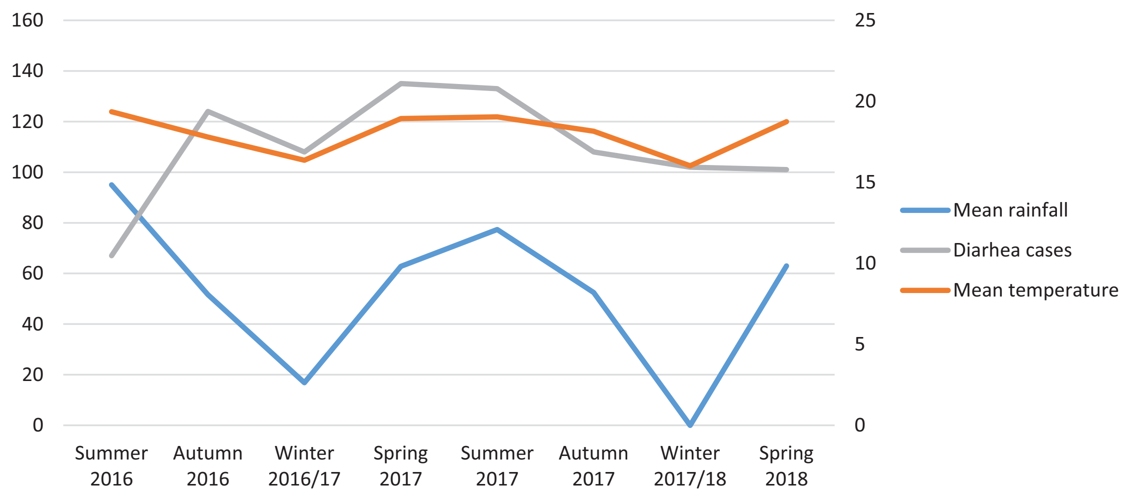

Figure 1. Trends of mean rainfall fall, mean temperature and diarrhoea cases in 8 waves, Kersa Demographic Surveillance and Research Center, Eastern Ethiopia, June 2016-May 2018.

The 3-month average of the climatic variability of the study sites revealed that a higher average air temperature of 19.36 (0.48) was observed in the main rainy season (June-August) and a lower average air temperature of 16.1 (1.22) was observed in the dry season (December to February). While the mean rainfall for 3 months varied from 95.05 mm (17.84) in the main rainy season (June to August) to 0 mm in the dry season (December to February) (Figure 1).

Factors associated with diarrhoea among under-five-year-old children

Multivariate analysis was performed using multilevel poisson regression for individual and community factors to control confounding and identify independent predictors of increasing diarrhoea episodes. We ran model 1 (empty model), model 2 (adjusted for individual factors), model 3 (adjusted for community-level factors) and model 4 (final model adjusted for individual and community-level factors) (Table 3).

The presence of E.coli in stored household water was significantly associated with an increase in the incidence of diarrhoea episodes (IRR = 1.68, 95% CI: 1.33-2.16), 11-100 (IRR = 1.49, 95% CI: 1.22-1.82), >100 (IRR = 1.70, 95% CI: 1.38-2.09), per capita consumption of drinking water consumption of 20 L (IRR = 1.71, 95% CI: 1.1. Treatment of household water (IRR = 0.68, 95% CI 0.48-0.96) was significantly associated with a decreased incidence of diarrhoea episodes after adjusting for the number of children in the household. The type of water source, residence, waste disposal, time spent collecting water, water transfer from storage container, paying for water, receiving WASH education and the place of the drinking cup were not statistically significant (Table 3).

Results of the spatiotemporal analysis

Child diarrhoea has shown random variation in the study area across water point locations. The most likely (primary) group (RR = 3.1, LLR = 54.1, *P*-value <.001) was identified in the north part of the study area (Belalange, name of kebele). The centre of the most likely cluster, which consisted of 2 locations of water points, was 9.412444 N, 41.818946 E and its radius was 2.29 km. Three secondary clusters of child diarrhoea were also identified in the north (Sodu and Metekoma kebeles) of the study area. Two no significant clusters (Yabetalencha and Gola kebeles) of child diarrhoea were observed in the southwest part of the study area (Tables 4 and 5 and Figure 2).

The space-time scan statistic also confirmed that child diarrhoea had random variation in both space and time. The most likely spatiotemporal cluster of child diarrhoea was located at 2 water points (RR = 4.55, LLR = 50.9, *P* < .001). From the six-round to the eighth round period, 2 significant secondary clusters were also identified that comprised 3 water point locations (RR = 2.41, LLR = 15.9, *P* < .001) in the second round to fifth round period and 11 water point locations (RR = 1.83, LLR = 14.4, *P* < .001) from the fourth round to fifth round period, respectively. Only one no significant secondary cluster of child diarrhoea was also observed in the fifth round period, comprising 4 water locations (RR = 1.92, LLR = 3.42, P = .950) (Table 6).

Discussion

The prevalence of diarrhoea among children under 5 years of age was 17.2% (95% CI 15.8-19.71) with a range of 11.2% in the first round to 20.36% in the fifth round. Spatiotemporal variation in diarrhoea was observed during the study period. Contamination of water at the source and at home, sharing of water sources with domestic animals, availability of urine in the compound, treatment of household water, 20 L per capita per day of water consumption, being a resident of the midlands, and average rainfall were significantly associated with diarrhoea.

Like in other developing countries, diarrhoea is a major public health problem in Ethiopia, especially among children under-five years of age.[16,18] The prevalence of diarrhoea in the current study is similar to the findings of a study conducted in

Table 3. Multilevel poison regression analysis of diarrhoea among under-five children in Kersa Demographic Surveillance and Research Center, East Ethiopia from 2016 to 2108.

	VARIABLE	MODEL 2 IRR (95% CI)	MODEL 3 IRR (95% CI)	MODEL 4 IRR (95% CI)
Individual level factors				
Household water with *E. coli*	<1	1.00		1.00
	1-10	1.65 (1.32-2.08) ***		1.68 (1.33-2.13) ***
	11-100	1.46 (1.20-1.77) ***		1.49 (1.22-1.82) ***
	>100	1.65 (1.35-2.03)***		1.70 (1.38-2.09)***
Type of water source	Public tape	1.00		1.00
	Protected well and spring	1.30 (0.98-1.72)		1.27 (0.95-1.70)
Access to drinking water	< 20 l	1.47 (1.23-1.76)***		1.47 (1.22-1.76)***
	⩾ 20 l	1.00		1.00
Number of children in the household	1	1.00		1.00
	2	1.81 (1.55-2.11)***		1.80 (1.54 -2.10)***
	3	2.70 (2.16-3.38)***		2.71 (2.16-3.40)***
Residence	Urban	1.00		1.00
	Rural	1.28 (0.93-1.77)		1.34 (0.96-1.87)
Waste disposal	Proper	0.96 (0.81-1.13)		0.96 (0.81-1.14)
	Improper	1.00		1.00
Time spent on water collection	<30 min	1.00		1.00
	⩾30 min	0.96 (0.87-1.05)		0.96 (0.87-1.05)
Water transfer from container	Pouring	1.00		1.00
	Dipping	1.06 (0.74-1.1.51)		1.07 (0.75-1.54)
Pay for water	No	1.00		1.00
	Yes	0.96 (0.81-1.13)		0.95 (0.80-1.12)
Household water treatment	No	1.00		1.00
	Yes	0.69 (0.49-0.96)*		0.68 (0.48-0.96)*
Faeces observed in the yard	No	1.00		1
	Yes	1.31 (1.11-1.54)***		1.31 (1.11-1.55)***
Received WASH education	Yes	1.00		1.00
	No	1.11 (0.95-1.29)		1.11 (0.95-1.30)
Animals share water sources	No	1.00		1.00
	Yes	1.68 (1.43-1.98)***		1.68 (1.42-1.98)***
Placement of drinking cup	On right place	1.00		1.00
	On the floor	1.05 (0.81-1.27)		1.01 (0.80-1.27)
Agro-ecological zone	High land	1.00		1.00
	Mid land	1.59 (1.07-2.37)*		1.71 (1.11-2.62)*
	Low land	1.24 (0.78-1.95)		1.22 (0.76-1.96)
Cluster level factors				
Average rainfall			1.03(1.01-1.08)*	1.03 (1.02-1.07)*
E. coli	0		1.00	1.00
	⩾1		1.214(1.057-1.976)*	1.27 (1.07-1.82)**

*$P < .05$. **$P < .01$. ***$P < .001$.
Abbreviations: IRR, incidence rate ratio.

Table 4. Result of the random intercept model for diarrhoea among children under 5 years of age using multilevel Poisson regression analysis.

MEASURE OF VARIATION	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Cluster level				
Variance (SE)	0.642 (0.081)	0.419 (0.065)	0.596 (0.081)	0.399 (0.072)

Model 1 empty model.
Model 2 is adjusted for individual factors.
Model 3 is adjusted for community-level factors.
Model 4 is the final model adjusted for individual and community-level factors.

Table 5. Spatial variation of child diarrhoea in the Kersa demographic surveillance and health research center, from June 2016 to May 2018.

VARIABLE	CLUSTER	WATER POINT LOCATION CODES	COORDINATION RADIUS	OBSERVED NUMBER	EXPECTED NUMBER	LLR	*P*-VALUE
Child diarrhoea	Most likely cluster	151, 152	9.412444 N, 41.818946 E) / 2.29 km	130	46.2	3.1	<.001
	Secondary cluster	161, 162, 166, 163, 22	9.414305 N, 41.864252 E / 2.80 km	153	100.41	1.64	<.001
	secondary cluster	21	9.452778 N, 41.859723 E / 0 km	38	19.86	1.96	.034
	Non-significant secondary cluster	32	9.453667 N, 41.760640 E / 0 km	37	20.08	1.88	.056
	Non-significant secondary cluster	91, 92, 93	9.299166 N, 41.721140 E / 1.03 km	71	47.82	1.53	.100

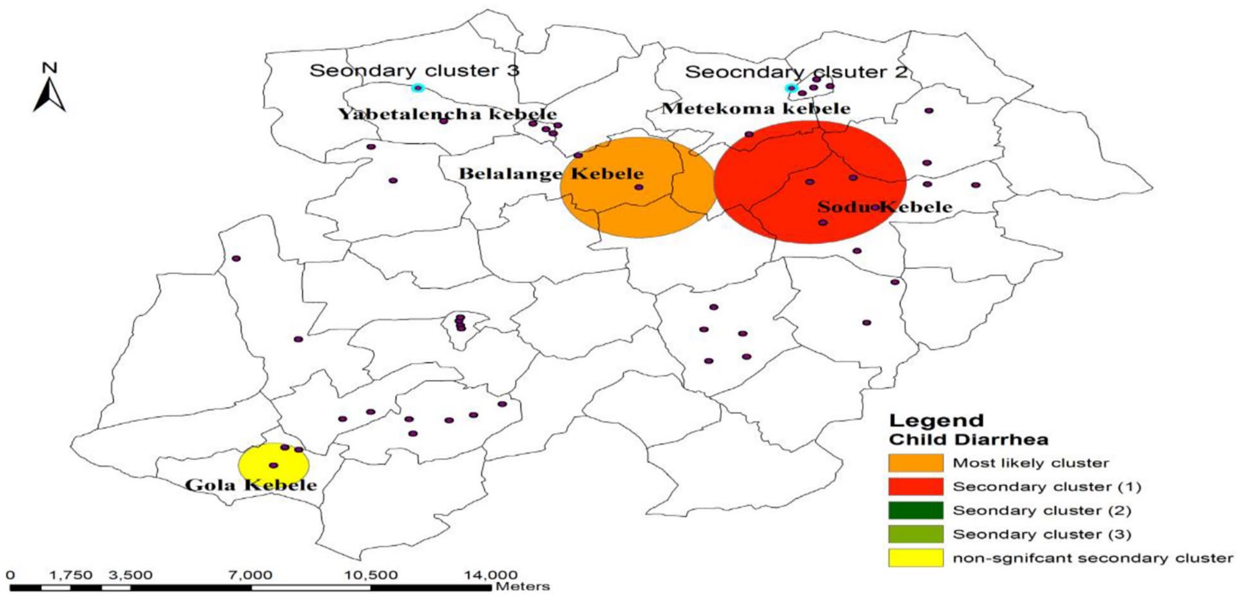

Figure 2. Spatial variation of child diarrhoea cases using pure spatial scan statistics in Kersa district, June 2016 to May 2018.

different parts of Ethiopia.[16,17] However, it is less than the study conducted in North West Ethiopia[18] and Ethiopian demographic and health survey 2011,[19] where the prevalence of diarrhoea among children under 5 years of age was 13.5% and 13%, respectively. During the study period, we observed seasonal variability in diarrhoea. A higher and lower prevalence of diarrhoea was observed during the summer of the first and second years of the study, respectively. The low prevalence of diarrhoea during the first summer year could be due to ongoing intervention due to the diarrhoea epidemic 2 months before the start of data collection.

In the present study, an increase in rainfall contributes to an increase in the number of diarrhoea episodes. This finding is consistent with a study conducted in India that indicated that high rainfall increased diarrhoea risks.[20] As rainfall increases, there is a risk of flooding, leading to both infrastructure damage and contamination of surface and groundwater supplies. This can hamper access to water and cause contamination and

Table 6. Spatiotemporal variation of child diarrhoea in Kersa Center for Demographic Surveillance and Health Research, June 2016 to May 2018.

VARIABLE	CLUSTER	WATER POINTS	LOCATION	START DATE	END DATE	LLR	P-VALUE
Child diarrhoea	Most likely cluster	151, 152	9.412444 N, 41.818946 E/2.29 km	Autumn 2017	Spring, 2018	4.55	<.001
	Secondary cluster	91, 92, 93	9.299166 N, 41.721140 E/1.03 km	Autumn, 2016	Summer, 2017	2.41	<.001
	Secondary cluster	163, 162, 166, 164, 167, 161, 182, 165, 191, 181, 22	9.403667 N, 41.881445 E/4.96 km	Spring 2017	Summer 2017	1.83	<.001
	Non-significant secondary cluster	113, 114, 111, 112	9.341028 N, 41.836862 E/2.47 km	Summer 2017	Summer 2017	1.92	.995

health risks. The pit latrines available in the study areas are also vulnerable to flooding and can cause serious environmental contamination that leads to diarrhoea. Given that the water systems are in poor structural condition and open defecation is common in the study area, the concentrations of bacteria at the source and storage of the household's water storage were influenced by the infiltration of faecal contamination from the environment, which is more likely to occur during periods of heavy rainfall and cause diarrhoea. Most latrines in rural areas are built with mud and roofed with local materials. These latrines are easily destroyed when there is a flood or heavy rain and contaminate the environment. Other studies conducted in Ecuador revealed that heavy rainfall events were associated with an increased incidence of diarrhoea after dry periods and a decreased incidence of diarrhoea following wet periods.[21]

There was a significant increase in the number of diarrhoea episodes in households with faeces observed in the compound. A similar finding was reported in a study conducted in Sodo Town, Ethiopia. The availability of urine in the compound is an indication of lack of latrine or lack of awareness of proper use that leads to contamination of the environment with faecal matter that can be the cause of diarrhoea.[22] Another study also indicated that the presence of excreta in the yard showed a strong association with diarrhoea morbidity among under-five children.[23] This implies that the mere presence of latrine facilities may not contribute to the prevention of excreta-related diseases unless accompanied by proper utilization.

In this study, sharing water sources with domestic animals was found to be associated with childhood diarrhoea. This finding is consistent with a systematic review conducted to determine the association of animal faeces with diarrhoea, showing that exposure to animal faeces has been associated with diarrhoea and soil-transmitted helminth infection.[24] Sharing water sources with domestic animals contaminates the water with animal faeces, which can play an important role in the transmission of some important aetiologies of childhood diarrhoea, such as Cryptosporidium, which contributes substantially to the childhood burden of diarrhoea disease.[25]

Studies reported that treating water at home improves the microbial quality of drinking water and reduces the risk of diarrhoea, particularly with consistent use.[26,27] Children whose families used home-based drinking water treatment such as boiling, the use of chemicals (eg aqua tabs and wuha-agar) and/or filtering were found to have lower odds of getting diarrhoea compared to children from families not treating water. This finding is consistent with the finding of other studies conducted in Ethiopia, which reported household water treatment as an independent predictor of diarrhoea.[22]

Under-five-year-old children living in households located in a midland agro-ecological zone had at high risk of a diarrhoea episode compared to households located in highland areas. Other studies indicated that higher temperature favours the growth of pathogenic organisms and increases bacterial and parasitic diarrhoea.[28] A study conducted in Bangladesh showed that ambient air temperature was positively associated with cases of non-cholera diarrhoea. The number of diarrhoea cases increase with higher temperature.[29] A study conducted in Peru reported an increase in hospital admission for diarrhoea with an increasing ambient temperature.[28]

In the current study, there is an increased risk of diarrhoea among under-five-year-old children in households with water contaminated with *E. coli* at the source and household water samples. This is consistent with the studies reported that *E.coli* contamination of water at the source and at home increase the possibility of diarrhoea.[30,31] *Escherichia coli* is the most common coliform among the intestinal flora of warm-blooded animals, and its presence could be associated with faecal contamination of animal or human origin.[32] There are hundreds of strains of *E. coli*, but only some strains are pathogenic. *Escherichia coli* has been implicated in diarrhoea ruptures in developing countries. Diarrhoeal disease due to *E.coli* is a major cause of morbidity and mortality, especially in children.[33]

The amount of water used at home is an important determinant of health.[34] The amount of water consumption per capita per day was significantly associated with under 5 diarrhoeal morbidities. This finding is in consistence with a study conducted in Ethiopia, which reported that mean per capita water consumption was lower in households where children had diarrhoea.[8] There is an evidence that an increased water consumption is associated with reduced gastrointestinal infection and diarrhoeal disease.[34]

Strengths and limitations of the study

One possible limitation of this study is that the data for child diarrhoea was collected using a self-report of mothers/women with a recall period of 2 weeks. Furthermore, *E. coli* was tested to indicate faecal contamination of water in the home and from sources. We could not perform a laboratory test for specific pathogens because it is expensive. Observation during data collection and information provided to the household during the previous visit may have some effect on the behaviour of study participants on the next data collection visit. However, the data collection interval was relatively long (2 months) and the data collection time was not communicated to the households. We believe that the learning effect could be minimal in the study.

Conclusions

Diarrhoea was found to be relatively high. Seasonal variation in diarrhoea was observed during the study period. Average rainfall, water contamination at the source and at home, sharing water sources with domestic animals, availability of urine in the compound, household water treatment, $<$20 L per capita per day of water consumption, Midland residents were significantly associated with diarrhoea. Therefore, to reduce the prevalence of diarrhoea, emphasis should be placed on climate-resilient interventions at the home and community levels.

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Authors' Contribution

Bezatu Mengistie, Tesfaye Gobena, Waltaji Terfa, Alemayehu Worku, Zerihun Bikila, Abera Kumie and Dinku Mekbib wrote the protocol, participated in the preparation of the data collection tool, and collected the data. Bezatu Mengistie, Tesfaye Gobena, Alemayehu Worku, Zerihun Bikila, Abera Kumie, Desalegn Admasu, Dinku Mekbib, Dechasa Adare Mengistu, and Muluken Azage participated in data analysis and manuscript writing. Finally, all authors approved the manuscript to be published.

Data Availability Statement

All data are included in this document.

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Supplemental Material

Supplemental material for this article is available online.

REFERENCES

1. Black RE, Cousens S, Johnson HL, et al. Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet*. 2010;375:1969-1987.
2. Bern C, Martines J, de Zoysa I, Glass RI. The magnitude of the global problem of diarrhoeal disease: a ten-year update. *Bull World Health Organ*. 1992;70:705-714.
3. World Health Organization. *Preventing Diarrhea Through Better Water, Sanitation and Hygiene: Exposures and Impacts in Low-and Middle-Income Countries*. World Health Organization; 2014.
4. Kosek M, Bern C, Guerrant RL. The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. *Bull World Health Organ*. 2003;81:197-204.
5. Phetsouvanh R, Midorikawa Y, Nakamura S. The seasonal variation in the microbial agents implicated in the etiology of diarrhoeal diseases among children in Lao People's Democratic Republic. *Southeast Asian J Trop Med Public Health*. 1999;30:319-323.
6. McGeehin MA, Mirabelli M. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. *Environ Health Perspect*. 2001;109 Suppl 2:185-189.
7. Bain R, Cronk R, Wright J, Yang H, Slaymaker T, Bartram J. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. *PLoS Med*. 2014;11:e1001644.
8. Teklemariam S, Getaneh T, Bekele F. Environmental determinants of diarrhoeal morbidity in under-five children, Keffa-Sheka zone, south west Ethiopia. *Ethiop Med J*. 2000;38:27-34.
9. Mekasha A, Tesfahun A. Determinants of diarrhoeal diseases: a community based study in urban south western Ethiopia. *East Afr Med J*. 2003;80:77-82.
10. Godana W, Mengistie B. Determinants of acute diarrhoea among children under five years of age in Derashe District, southern Ethiopia. *Rural Remote Health*. 2013;13:2329.
11. Anteneh ZA, Andargie K, Tarekegn M. Prevalence and determinants of acute diarrhea among children younger than five years old in Jabithennan District, Northwest Ethiopia, 2014. *BMC Public Health*. 2017;17:99-108.
12. Charles P, Silesh L, Tigist K; USAID/Ethiopia. Childhood diarrhoea. In: Berhane Y, Mariam DH, Kloos H, eds. *Epidemiology and Ecology of Health and Disease in Ethiopia*. Shama Books; 2006.
13. WHO Ethiopia. 2014. Systematic Review and Meta-Analysis of national relevant evidence of effectiveness of household and community water, saniation and hygiene (WASH) and climate resilient interventions in Ethiopia-Building adaptation to climate change in health in least developed countries through resilient WASH (unpublished).
14. Assefa N, Oljira L, Baraki N, et al. HDSS profile: the kersa health and demographic surveillance system. *Int J Epidemiol*. 2016;45:94-101.
15. Federal Democratic Republic of Ethiopia Population Census Commission. *The 2007 Population and Housing Census of Ethiopia Results for Somali Region Statistical Report*. Central Statistical Agency; 2010.
16. Mengistie B, Berhane Y, Worku A. Prevalence of diarrhea and associated risk factors among children under-five years of age in eastern Ethiopia: A cross-sectional study. *Open J Prev Med*. 2013;03:446-453.

17. Dessalegn M, Kumie A, Tefera W. Predictors of under-five childhood diarrhoea: Mecha District, west gojam, Ethiopia. *Ethiop J Health Dev*. 2011;25:192-200.
18. Azage M, Kumie A, Worku A, Bagtzoglou AC. Childhood diarrhea in high and low hotspot districts of Amhara Region, northwest Ethiopia: a multilevel modeling. *J Health Popul Nutr*. 2016;35:13.
19. Usaid S, Moh U, Unfpa U, Ehnri C. *Ethiopia Demographic and Health Survey 2011*. Central Statistical Agency Addis Ababa, Ethiopia ICF International Calverton, MD; 2012.
20. Kulinkina AV, Mohan VR, Francis MR, et al. Seasonality of water quality and diarrheal disease counts in urban and rural settings in south India. *Sci Rep*. 2016;6:20521.
21. Carlton EJ, Eisenberg JN, Goldstick J, Cevallos W, Trostle J, Levy K. Heavy rainfall events and diarrhea incidence: the role of social and environmental factors. *Am J Epidemiol*. 2014;179:344-352.
22. Tarekegn M, Enquselassie F. A case control study on determinants of diarrhoeal morbidity among under-five children in Wolaita Soddo Town, Southern Ethiopia. *Ethiop J Health Dev*. 2012;26:78-85.
23. VanDerslice J, Popkin B, Briscoe J. Drinking-water quality, sanitation, and breast-feeding: their interactive effects on infant health. *Bull World Health Organ*. 1994;72:589-601.
24. Penakalapati G, Swarthout J, Delahoy MJ, et al. Exposure to animal feces and human health: a systematic review and proposed research priorities. *Environ Sci Technol*. 2017;51:11537-11552.
25. Kotloff KL, Nataro JP, Blackwelder WC, et al. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. *Lancet*. 2013;382:209-222.
26. Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM Jr. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect Dis*. 2005;5:42-52.
27. Clasen TRI, Rabie T, Schmidt WP, Cairncross S. *Interventions to Improve Water Quality for Preventing Diarrhoea (Cochrane Review)*. The Cochrane Library, Update Software, 3 2006; 2006.
28. Checkley W, Epstein LD, Gilman RH, et al. Effects of EI Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet*. 2000;355:442-450.
29. Hashizume M, Armstrong B, Hajat S, et al. Association between climate variability and hospital visits for non-cholera diarrhoea in Bangladesh: effects and vulnerable groups. *Int J Epidemiol*. 2007;36:1030-1037.
30. Moe CL, Sobsey MD, Samsa GP, Mesolo V. Bacterial indicators of risk of diarrhoeal disease from drinking-water in the Philippines. *Bull World Health Organ*. 1991;69:305-317.
31. Rompré A, Servais P, Baudart J, de-Roubin MR, Laurent P. Detection and enumeration of coliforms in drinking water: current methods and emerging approaches. *J Microbiol Methods*. 2002;49:31-54.
32. O Owolabi AA. Domestic water use, sanitation and diarrhea incidence among various communities of Ikare – Akoko, Southwestern, Nigeria. *Afr J Microbiol Res*. 2012;6:3465-3479.
33. Hunter PR. Drinking water and diarrhoeal disease due to Escherichia coli. *J Water Health*. 2003;1:65-72.
34. Stelmach RD, Clasen T. Household water quantity and health: a systematic review. *Int J Environ Res Public Health*. 2015;12:5954-5974.