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BMJ Open

Temporal trends and spatial heterogeneity of sanitation facilities in Ethiopia: evidence from the 2005-2019 Demographic and Health Surveys

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Complete List of Authors:	Azanaw, Jember; University of Gondar, Department of Environmental and Occupational Health and Safety Tsegaye, Mesenbet; University of Gondar, Department of General Surgery Mesele, Wodaje; University of Gondar, Department of Orthopaedic and Trauma Surgeon
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26 Abstract

Background: The main aim of sanitation is to prevent human contact with fecal pathogens to
decrease occurrences of diseases. But, no region in the world is on the right track to accomplish
SDG 6.2 for universal access to sanitation. SSA, Ethiopia included, is significantly behind in
meeting the 2030 SDG 6.2 targets. Hence, this study focused on the spatial and temporal analysis
of sanitation in Ethiopia based on four demographic health surveys.

Method: This research was undertaken in Ethiopia based on a weighted sample size. Variables with a p-value below 0.2 in bivariable analysis were incorporated into the multivariable analysis. Subsequently, a 95% CI and a p-value < 0.05 were utilized to assess the statistical significance of the final model. Global and local indicators of spatial correlation were done. Statistical analyses were performed using STATA 17, and ArcGIS 10.7 software.

Results: This study includes 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in 2019 EDHS 8,663 participants. The prevalence of improved sanitation facilities in Ethiopia was 20.46%, 25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively. Global Moran's I spatial autocorrelations, hotspots, and spatial interpolation analysis indicated the inequality of improved sanitation facilities. Educational status of primary (AOR = 2.43, 95% CI : (2.00, 2.95), secondary (AOR = 2.02, 95% CI : (1.61, 2.54)), and higher (AOR = 4.12, 95% CI : (3.35, 7.54), watching television (AOR= 5.49, 95% CI: (4.37, 6.89)), (AOR= 9.08, 95% CI: (6.69, 12.33), and region were factors statistically associated with sanitation facilities.

45 Conclusion: The overall finding of this study concludes a very slow increment in sanitation
46 facilities over time and presence of geographical heterogeneity in Ethiopia. Educational status,
47 watching television, wealth index, community-level education, type of residence, and region were
48 factors statistically associated with sanitation facilities.

49 Keywords: EDHS, Ethiopia, Improved Sanitation, Spatiotemporal variation

54 Background

Sanitation refers to the endowment of services and facilities for the safe and clean controlling of
human excreta, from the toilet to handling and containment to the final end-use or removal [1].
Sanitation is an integral component of basic human rights comparable to food, shelter, and water
and is vital for healthy life [2].

According to the United Nations (UN-2018) report, in the world, around 4.5 billion people had no safe sanitation and 1.8 billion use contaminated water by human excreta, and 892 million continue to practice Open Defecation (OD) [3, 4]. Inadequate access to sanitation is a principal reason for poverty in unindustrialized nations because it causes early mortality [5, 6]. According to World Health Organization (WHO) 2019 estimation, drinking water sources of two billion people were contaminated with feces and over 800,000 people die annually from diarrhea caused by poor water, sanitation, and hygiene (WASH) (World Health Organization, 2019). In Eastern and Southern Africa, 340 million people (more than 70%) have no access to basic sanitation services, 98 million people (19 percent) practice open defecation, 179 million use unimproved facilities, and 63 million shared sanitation facilities [7].

Due to such problems, Sustainable Development Goals (SDGs 6.2) stand to ensure accessibility of equitable sanitation for all by the year 2030 [8]. SDG 6.2 of the United Nations, which emanated in 2015 from the Millennium Development Goals, aims at equitable access to safe and affordable sanitation for all by 2030 (10). The main aim of this SDG is to prevent human contact with fecal pathogens to decrease occurrences of diseases [9, 10]. Nevertheless, no region in the world is on the right track to accomplish SDG 6.2 for universal access to sanitation, and urban sewer connections are increasing at an embarrassingly slow rate of 0.14% annually [11]. Especially, countries in Sub-Saharan Africa (SSA) countries are extremely late to achieve SDG 6.2 2030 agenda due to the rapid population growth rate, without enough investment in sanitation infrastructures [12, 13]. At the same time, inequalities in accessing sanitation facilities were more pronounced among countries in sub-Saharan Africa [14]. There is a disparity within countries, mainly regarding urban and rural residences, which indicated that rural inhabitants access markedly lower levels of sanitation than with urban residences [15]. Such Subnational variation in access to improved sanitation facilities, defined as the range of values from the unit with the highest level of access to the unit with the lowest level or no access, are evident across low and

middle income countries [16]. Like other developing countries [17] access to sanitation is a
challenge across Ethiopia [18], as well as there are disparities among the regions of the country.
On the other hand nations may strengthen or setback the progress of equitable access to improved
sanitation facilities.

Previous studies in Ethiopia were based on a single EDHS or only multilevel analysis or spatial analysis in order to investigate improved sanitation facilities [19]. Such studies unable to show the trend of improved sanitation facilities progress overtime. Residence, educational attainment, watching television, household size, region, and wealth index are factors associated with the improved sanitation source as in previous studies [20-22]. Hence, this study focused on the spatial and temporal analysis of sanitation facilities in Ethiopia based on combined multiple (2005, 2010, 2016, and 2019) demographic health surveys for better understanding of the progress and geographic variation within the country.

96 Methods

97 Study area and Data source

This study was conducted in Ethiopia, which is nine geographical regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples Region (SNNPR), Gambella, and Harari), and two administrative cities (Addis Ababa and Dire-Dawa) of the country. The country is located in the Horn of Africa with geographical locations 9.145° N latitude and 40.4897° East longitude [23]. This study used the four successive Ethiopian Demographic and Health Surveys (EDHS 2005, 2011, 2016, and 2019) database survey. Therefore, these are nationally representative population-based surveys with large sample sizes at different times. EDHS data is open source and can be retrieved on the DHS website https://www.dhsprogram.com/data/dataset admin/login main.cfm.

All EDHS samples were a two-stage stratified cluster sample [24], sampling weights were calculated based on sampling probabilities separately for each sampling stage and each cluster. In 2005 surveys, 540 enumeration areas (EAs) (139 urban and 401 rural areas), 2011 EDHS, 624 EAs (187 urban and 437 rural areas), 2016 EDHS 645 EAs (202 in urban areas and 443 in rural areas), and 2019 EDHS 305 EAs (93 in urban areas and 212 in rural areas) were selected using systematic sampling with likelihood proportional to size.

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In the second stage of selection, a fixed number of 30 households per cluster were selected with an equal probability of systematic selection from the newly created household listing. The field practice was conducted in Adama in clusters that were not part of the survey sample. Ethiopian public health institute investigators, an ICF technical specialist, an advisor, and representatives from other organizations, including central statistics agency, the Federal Ministry of Health, the World Bank, and USAID, supported the data collection.

Among included households, 13,721, 16,702, 16, 650, and 8,663 were successfully interviewed in EDHS 2005, 2011, 2016, and 2019, respectively. Weighted by sampling weight was done to do a reliable statistical analysis. The geographical location data were taken from selected respective Enumeration Areas (EAs).

123 Study Variables

124 Outcome variables

The dependent variable was the sanitation facilities. The water source categorized as '1' on behalf of 'improved sanitation' which accessed from flush/pour flush to piped sewer systems, septic tanks, or pit latrines; ventilated improved pit latrines, composting toilets or pit latrines with slabs, and '0' for 'unimproved sanitation' when the sanitation facilities from pit latrines without a slab or platform, hanging latrines or bucket latrines and open defecation [25-27].

6 130 **Predictor variables**

Individual level variables: sex of household head (male or female), wealth index (poor, middle, and rich), educational status (no education, primary education, secondary education, and higher education), having a television (yes or no) and radio (yes or no) were individual-level predictor variables.

Community level variables: Community level education (lower/higher), the place of residence
 (urban/rural), community level media exposure (exposed/unexposed), region (Benishangul Gumuz, Somali, Gambella, Afar, Oromia, SNNPR, Amhara, Tigray, and Harari) and City
 administration (Addis Ababa, and Dire Dawa).

- 56 140

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Data management and analysis For data quality assurance purposes, pretests containing in-class training, biomarker training, and field exercise were done. The field exercise was conducted in clusters, which were not included in the EDHS sample. A debriefing session was held with the pretest field staff, and adjustments to the questionnaires were done based on lessons drawn from the field practice. Since the outcome variables were dichotomous, logistic regression analysis was conducted to assess associations of outcome variables and predictor variables. Variables in bivariable analysis with a p-value less than 0.2 were included in multivariable binary logistic regression analysis. 95% confidence interval (CI) and a p-value less than 0.05 were used for identifying statistical significance in the final model [28]. **Multilevel Analysis** Four models, a null model (model 0) without any predictor variable, model 1 comprised dependent and individual-level predictors, model 2 incorporated dependent and community-level predictors, and model 3 involved the dependent variables and all individual- and community- level predictors were established. Random effects were measured using cluster variance (Vc), a proportional change in variance ((PCV ((Vc - Vn)/Vc)) the intraclass correlation coefficient (ICC (Vc/(Vc + 3.29)), and the median odds ratio (MOR (exp [(0.95) \sqrt{Vc}])) [29, 30]. The goodness-of-fit for all models was evaluated using AIC, BIC, and Deviance. Then the model with the lower value of deviance, AIC, and BIC, was demonstrating the best-fit model [31]. As well as

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factor (VIF).

Spatial analysis

Spatial Autocorrelation

To explore the geographical distribution, both global and local indicators of spatial correlation are the best imperative tools for access to improved sanitation facilities within the specified period.

multicollinearity, the effect of independent variables was measured using the variance inflation

Global autocorrelations

To proceed with geographical variation identification of access to improved sanitation facilities. Global autocorrelations analysis was done. Global spatial autocorrelation (Moran's I index) was

used to detect whether the difference is due to the clustering effect or non-random/dispersion [32,

170 33]. As well as the simple exploratory spatial analysis was performed to identify the presence of

171 improved sanitation facilities and geographical dependence distribution in the country.

172 Local statistical analysis

Further investigation using figures and maps is needed since Global autocorrelations indicate a clustering effect (positive spatial autocorrelation) on sanitation facilities' access over the country. Therefore, hotspot analysis (Gettis-Ord Gi*) was performed to identify patterns of spatial variation and emphasize the previously stated using global autocorrelations (cluster effect) on access to sanitation facilities. Cluster and outlier analysis (Anselin local Moran is I) was used to describe the spatial patterns of the dependent variables (access to sanitation facilities). This cluster and outlier analysis was used to confirm and accompaniment to show extreme (the hotspot and cold spot) since it permits the identification of groupings and areas where the differences happen [34].

181 Results

28 29 182 Socio-demographic characteristics of the study population

This study include 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in
2019 EDHS 8,663 participants. In all EDHS, data sets the greater proportion (63.59%, 55.74%,
52.06%, and 47.65%, respectively) of study subjects were no education. The majority (88.30%,
81.68%, 76.98%, and 77.10%) of the participants in the 2005 EDHS, 16,702the in the 2011 EDHS,
16,650 in the 2016 EDHS, and 2019 EDHS, respectively, had no television (Table 1).

188 Table 1. Socio-demographic characteristics of study Participants in Ethiopia

Variables	EDHS 2005	EDHS 2011	EDHS 2016	EDHS 2019
	(N=13,721)	(N=16,702)	(N= 16,650)	(N= 8,663)
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Sex of HHH				
Male	10,243(74.65)	11,906(71.28)	11,413(68.55)	6,291(72.62)
Female	3,478(25.35)	4,796 (28.72)	5,237(31.45)	2,372(27.38)
Age of HHH				
<30	3,428(24.98)	4,823(28.88)	4,257(25.57)	2,520(29.09)

30-40	3,501(25.52)	
41-54	3,756(27.37)	
>54	3,036(22.13)	
Educational status of	f	
ННН		
No education	8,725(63.59)	
Primary	2,705(19.71)	
Second	1,754(12.78)	
Higher	495(3.61)	
Wealth index		
Poor	5,393(39.30)	
Middle	2,055(14.98)	
Rich	6,273(45.72)	
Share toilet with other	households	
Yes	2,712(45.72)	
No	3,204(54.01)	
Having radio		
No	8,157(59.45)	
Yes	5,560(40.52)	
Having Television		
No	12,116(88.30)	
Yes	1,601(11.67)	
Community-level		
media exposure		
Unexposed	8,105(59.07)	
Exposed	5,616(40.93)	
Community-level		
educational status		
Lower	8,730(63.63)	
	4,991(36.37)	

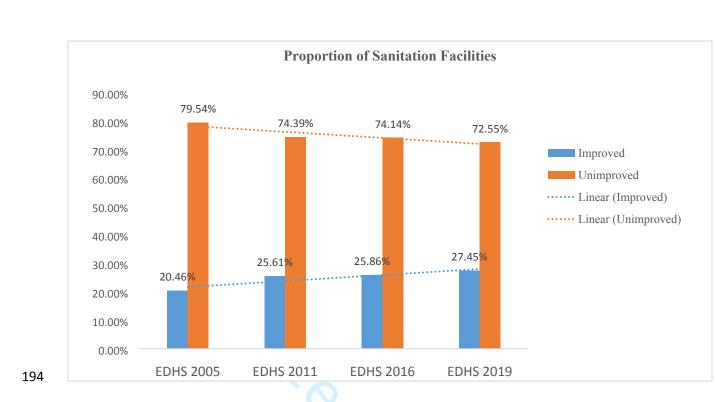
30-40	3,501(25.52)	4,116(24.64)	4,132(24.82)	2,287(26.40)
41-54	3,756(27.37)	4,047(24.23)	4,230(25.41)	1,717(19.82)
>54	3,036(22.13)	3,716(22.25)	4,031(24.21)	2,139(24.69)
Educational status of				
ННН				
No education	8,725(63.59)	9,309(55.74)	8,668(52.06)	4,128(47.65)
Primary	2,705(19.71)	5,020(30.06)	4,658(27.98)	2,715(31.34)
Second	1,754(12.78)	1,189(7.12)	1,686(10.12)	963(11.12)
Higher	495(3.61)	1,140(6.83)	1,580(9.49)	857(9.89)
Wealth index	1			
Poor	5,393(39.30)	6,506(38.95)	7,024(42.19)	3,498(40.38)
Middle	2,055(14.98)	2,364(14.15)	2,057(12.35)	1,285(14.83)
Rich	6,273(45.72)	7,832(46.89)	7,569(45.46)	3,880(44.79)
Share toilet with other	households		1	1
Yes	2,712(45.72)	4,467(46.12)	4,727(43.83)	2,222 (38.18)
No	3,204(54.01)	5,204(53.73)	6,059(56.17)	3,598(61.82)
Having radio				
No	8,157(59.45)	9,658(57.83)	11,680(70.15)	6,170 (71.22)
Yes	5,560(40.52)	7,040(42.15)	4,970(29.85)	2,493(28.78)
Having Television			0	
No	12,116(88.30)	13,643(81.68)	12,818(76.98)	6,679 (77.10)
Yes	1,601(11.67)	3,051(18.27)	3,832(23.02)	1,984(22.90)
Community-level				
media exposure				
Unexposed	8,105(59.07)	8,973(53.72)	10,024(60.20)	5,195(59.97)
Exposed	5,616(40.93)	7,729(46.28)	6,626(39.80)	3,468(40.03)
Community-level				
educational status				
Lower	8,730(63.63)	9,309(55.74)	8,726(52.41)	4,308(49.73)
Higher	4,991(36.37)	7,393(44.26)	7,924(47.59)	4,355(50.27)
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Residence				
Urban	3,666(26.72)	5,112(30.61)	5,232(31.42)	2,645(30.53)
Rural	10,055(73.28)	11,590(69.39)	11,418(68.58)	6,018(69.47)
Region				
Tigray	1,282(9.34)	1,730(10.36)	1,734(10.41)	714(8.24
Afar	806(5.87)	1,267(7.59)	1,220(7.33)	664 (7.66)
Amhara	2,066(15.06)	2,071(12.40)	1,902(11.42)	1,007(11.62)
Oromia	2,155(15.71)	2,165(12.96)	1,988(11.94)	1,018(11.75)
Somali	796(5.80)	975(5.84)	1,564(9.39)	657(7.58)
Benishangul-Gumuz	869(6.33)	1,323(7.92)	1,280(7.69)	734(8.47)
SNNPR	1,933(14.09)	2,045(12.24)	1,897(11.39)	1,017(11.74)
Gambella	820(5.98)	1,215(7.27)	1,280(7.69)	693(8.00)
Harari	904(6.59)	1,201(7.19)	1,135(6.82)	719(8.30)
Addis Ababa	1,333(9.72)	1,524(9.12)	1,489(8.94)	702(8.10)
Dire Dawa	757(5.52)	1,186(7.10)	1,161(6.97)	738(8.52)

Trends of Sanitation facilities in Ethiopia

Figure 1 below presented that the trend of improved sanitation facilities in Ethiopia was 20.46%, 25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively (figure 1).





196 Factors Associated with Sanitation Facilities Accessibility

The odds of accessibility to improved sanitation facilities among participants with educational status of primary, secondary, and higher were 2.43 (AOR = 2.43, 95% CI :(2.00, 2.95)), 2.02 (AOR = 2.02, 95% CI :(1.61, 2.54)), and 4.12 (AOR = 4.12, 95% CI :(3.35, 7.54) times more likely respectively, compared to those with no education.

Study participants with wealth status of the middle, and rich were 1.49 (AOR = 1.49, 95% CI :(
1.21, 1.83)), and 3.15 (AOR = 3.15, 95% CI :(2.55, 3.89)) times more likely in the odds of
accessing improved sanitation facilities respectively, compared to those counterparts poor.

The odds of accessing improved sanitation facilities among study participants watched television
were 5.49 (AOR= 5.49, 95% CI: (4.37, 6.89)) more likely compared to counterparts who did no
watching television.

Community-level education was a statistically significant predictor variable. The odds of accessing improved sanitation facilities among Communities with higher educational levels were 3.90 (AOR= 3.90, 95% CI: (3.15, 4.82) times more likely compared to the community with lower education.

The chance of accessing improved sanitation facilities among communities exposed to media was 5.61 (AOR= 5.61, 95% CI: (3.84, 10.09)) times more likely than in the community unexposed to the media. The odds of accessibility-improved sanitation facilities among the study population living in urban areas were 9.08 (AOR= 9.08, 95% CI: (6.69, 12.33) times more likely compared to the o study population living in rural areas. Communities across various regions, including Tigray (54% less likely, AOR=0.46; 95% CI: 0.37, 0.57), Afar (33% less likely, AOR=0.67; 95% CI: 0.51, 0.86), Somali (77% less likely, AOR=0.23; 95% CI: 0.18, 0.29), Amhara (60% less likely, AOR=0.40; 95% CI: 0.32, 0.49), Benishangul Gumuz (37% less likely, AOR=0.63; 95% CI: 0.49, 0.80), Gambella (55% less likely, AOR=0.45; 95% CI: 0.35, 0.57), Harari (36% less likely, AOR=0.64; 95% CI: 0.52, 0.80), SNNRP (72% less likely, AOR=0.28; 95% CI: 0.22, 0.34), and Dire Dawa (72% less likely, AOR=0.28; 95% CI: 0.22, 0.35), exhibit decreased access to improved sanitation facilities compared to communities in Addis Ababa. The random variations of sanitation were demonstrated by intra-cluster correlation coefficient (ICC), Proportion Change in Variance (PCV), and median odds ratio (MOR). The ICC in the null model showed that 67.65% of the total variability in accessing improved sanitation facilities was due to differences through cluster areas. Model 1 and Model 2 presented that 59.74% and 26.35% of the Proportion Change in Variance (PCV) of the variation in accessing improved sanitation in the communities was explained by individual and community-level factors, respectively. The MOR between the area at highest in accessing improved sanitation facilities and the area at lowest in accessing improved sanitation facilities if randomly picking out two areas was 7.07. The goodness fit in model statistics indicated using the lowest values of AIC, DIC, and Deviance. Therefore, the final model had the lowest AIC, DIC, and Deviance, 11151.08, 11282.33, and 11,117.0824, respectively which confirmed the best-fit model (Table 2)

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Table 2. Multilevel binary logistic regression analysis of predictors towards accessibility ofsanitation facilities in Ethiopia, EDHS 2011

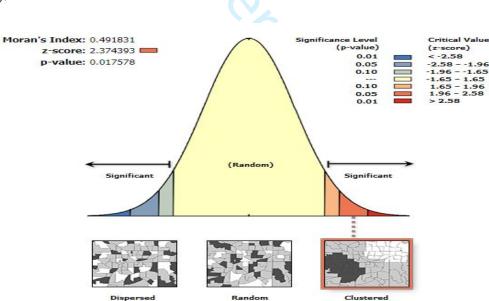
Variables	Model	Model 1	Model 2	Model 3
	0 (Null	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
	model)			
Individual lev	el Factors			
Sex of HHH				
Male		0.97(0.82,1.04)		1.01(0.84,1.11)
Female		1	1	1
Age of HHH				
<30		0.97(0.94,1.01)		0.96 (0.20,2.34)
30-40		0.57(0.35,2.02)		1.49(0.13,2.41)
41-54		0.43(0.22,0.61)		1.17(0.86,1.59)
>54		1	1	1
Educational sta	atus			
No education		1	L.	1
Primary		3.23 (2.63,3.96)**	6	2.43(2.00,2.95)**
Secondary		6.36(5.26,7.67)**		2.02(1.61,2.54)**
Higher		8.11 (7.16,9.19)*		4.12(3.35,7.54)**
Wealth index			0.	
Poor		1		1
Middle		2.96 (2.34,4.24)**		1.49 (1.21,1.83)**
Rich		5.48 (3.45,5.89)**		3.15(2.55,3.89)**
Having televisi	ion			
No		1		1
Yes		4.81(4.16,5.56)**		5.49(4.37,6.89)**
Community le	evel factors) }	1	
Community lev	vel education	on		
Higher			6.50(5.82,7.27)**	3.90(3.15,4.82)**
Lower			1	1

Exposed				6.07(5.42,6.81)**		5.61(3.84,10.09)**		
Unexposed				1		1		
Type of residence	;							
Urban				16.74(11	.85, 23.65)**	9.0	8(6.69,12.33)**	
Rural				1		1		
Region								
Tigray				0.50(0.41	,0.62)**	0.4	6(0.37,0.57)**	
Afar				0.86(0.67	7,1.09)	0.6	7(0.51,0.86)*	
Amhara		~		0.43(0.35	5,0.53)**	0.4	0(0.32,0.49)**	
Oromia		6		0.89 (0.7	2,1.09)	0.9	0(0.73,1.12)	
SNNRP		N		0.25(0.20),0.31)*	0.2	8(0.22,0.34)**	
Somali		(0.33(0.26	6,0.41)**	0.23(0.18,0.29)**		
Benishangul				0.74(0.59,0.94)*		0.63(0.49,0.80)**		
Gumuz								
Gambella				0.51(0.41,0.64)**		0.4	5(0.35,0.57)**	
Harari			6			0.6	4(0.52.0.80)**	
Addis Ababa				1		1		
Dire Dawa				0.25(0.21	,0.31)**	0.2	8(0.22,0.35)**	
VIF		2.35		2.27	0	2.0	5	
Measures of varia	tions for	sanitation			5			
Variance	6.88	(5.84,8.10)	2.77(2.30	,3.32)	2.04(1.71,2.44))	1.97(1.65,2.35)	
MOR	7.07		4.35		3.82		3.78	
PCV	CV Reference 59.74%			26.35%		3.43 %		
ICC	0.67	65	0.4571		0.3827		0.3745	
Model fitness test	statistic	S						
AIC	1220	04.07	11338.86		11610.79		11151.08	
BIC	1221	19.51	11454.67		11734.32		11282.33	
Deviance	12,2	00.0736	11,323.61	74	11611.497		11,117.0824	

	Oper
), AIC=Akaike's	1: firs
HH=household,	t pub
d for individual-	olishe
the final model	id as
	10.11 Pro
f 2005 EDHS 348) indicated hiopia (Figure	Open: first published as 10.1136/bmjopen-2024-088211 on 3 December 2024. Downloaded from http://bmjopen.bmj.com/ on June 10, 2025 at Agence Bibliographique de l Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
	del

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1= reference, **P-value < 0.001 (Adjusted OR), *P-value < 0.05 (Adjusted OR) information criteria, BIC=Bayesian information criteria, HHH =household head, Model 0 (Null model) was fitted without predictor variables. ; Model 1 is adjuste level variables. Model 2 is adjusted for community-level variables; Model 3 is adjusted for both individual- and community-level predictors. 2).



Analysis of spatial heterogeneity

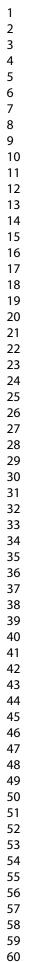
Spatial autocorrelation (Moran's I)

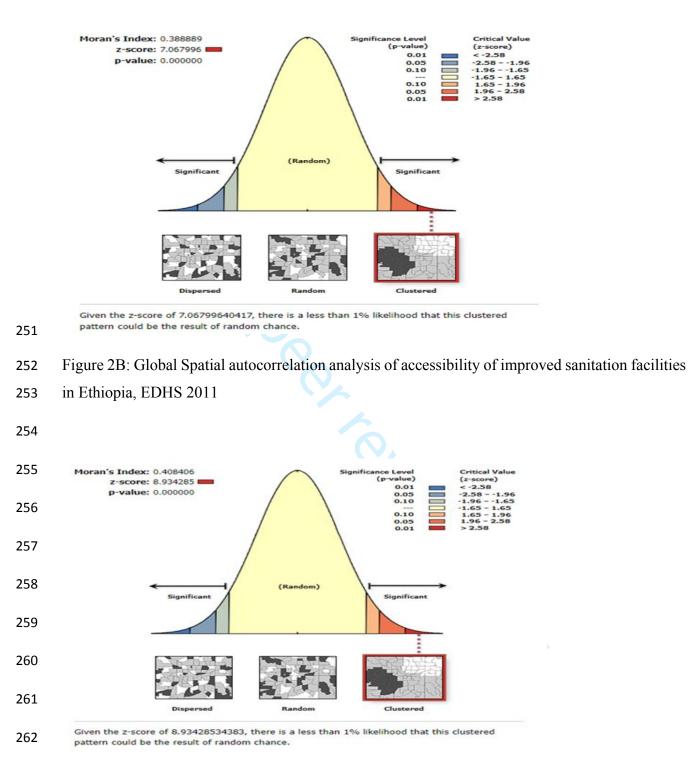
Global Moran's I spatial autocorrelations positive z-scores (with the z-scores of 2.374393,2011 EDHS 7.067996, 2016 EDHS 8.9374285, and 2019 EDHS 36.511 that all EDHS were clustered in accessing improved sanitation facilities through Etl

Given the z-score of 2.37439300313, there is a less than 5% likelihood that this clustered pattern could be the result of random chance.

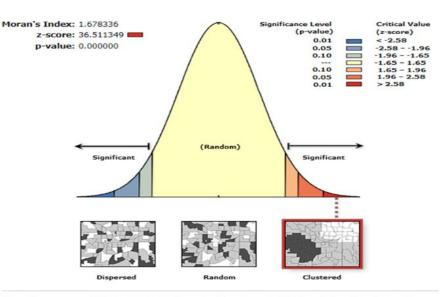
Figure 2A: Global Spatial autocorrelation analysis of accessibility of improved sani

facilities in Ethiopia, EDHS 2005.

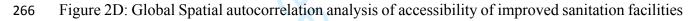




- Figure 2C: Global Spatial autocorrelation analysis of accessibility of improved sanitation facilities
- in Ethiopia, EDHS 2016



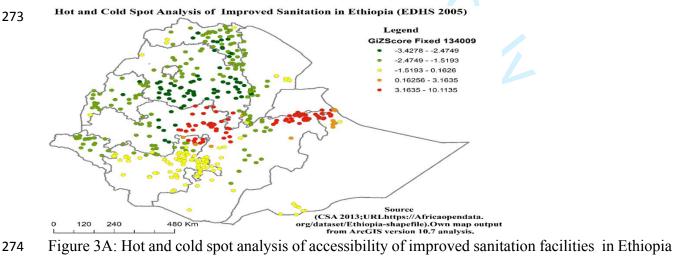
Given the z-score of 36.5113487033, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.



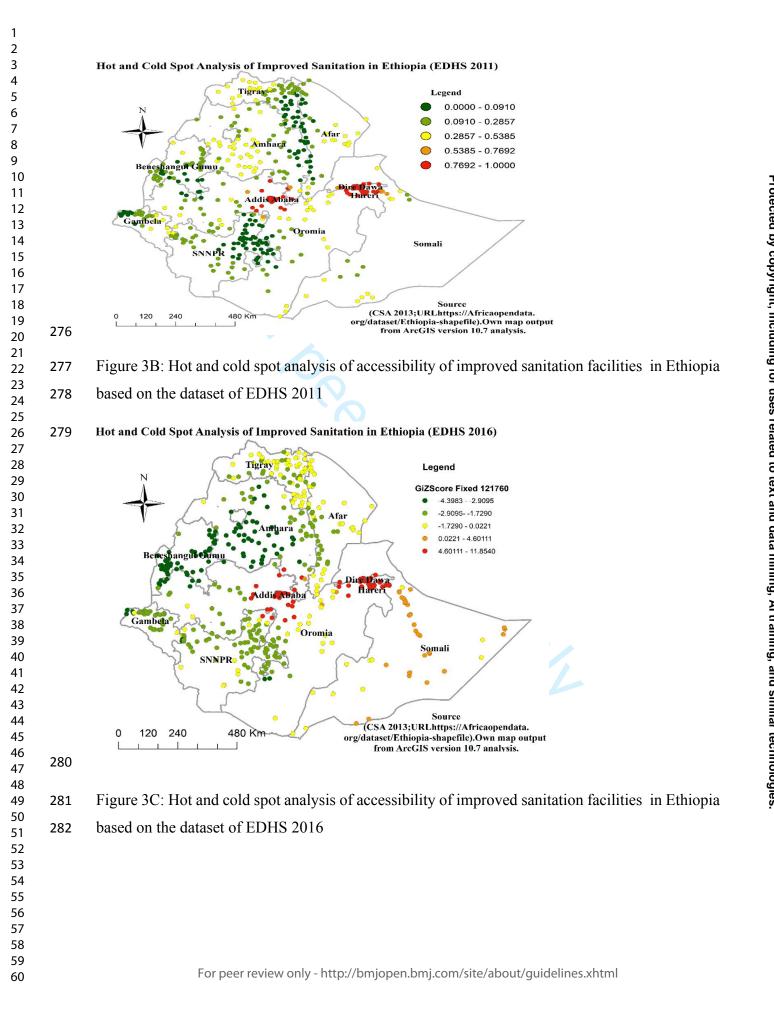
267 in Ethiopia, EDHS 2019

268 Hot and cold spot analysis (Getis-Ord Gi*)

Hot and cold spot analysis revealed that there was the same trend in spatial distribution of improved sanitation facilities through Ethiopia in all EDHS. The figures below show that in all EDHS the percentage of accessing improved sanitation was significantly lower in most parts of the country while this proportion was better only in Addis Ababa, and Dire Dawa (Figure 3).



based on the dataset of EDHS 2005



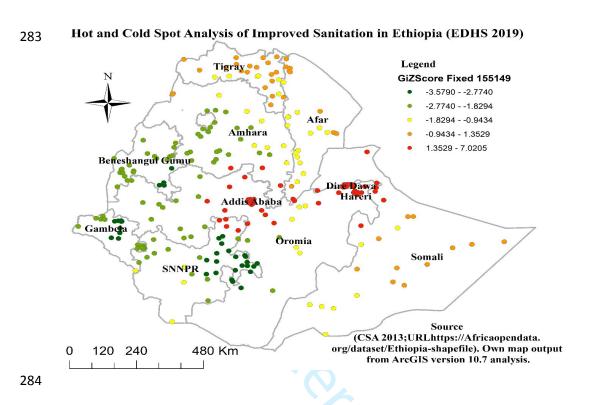
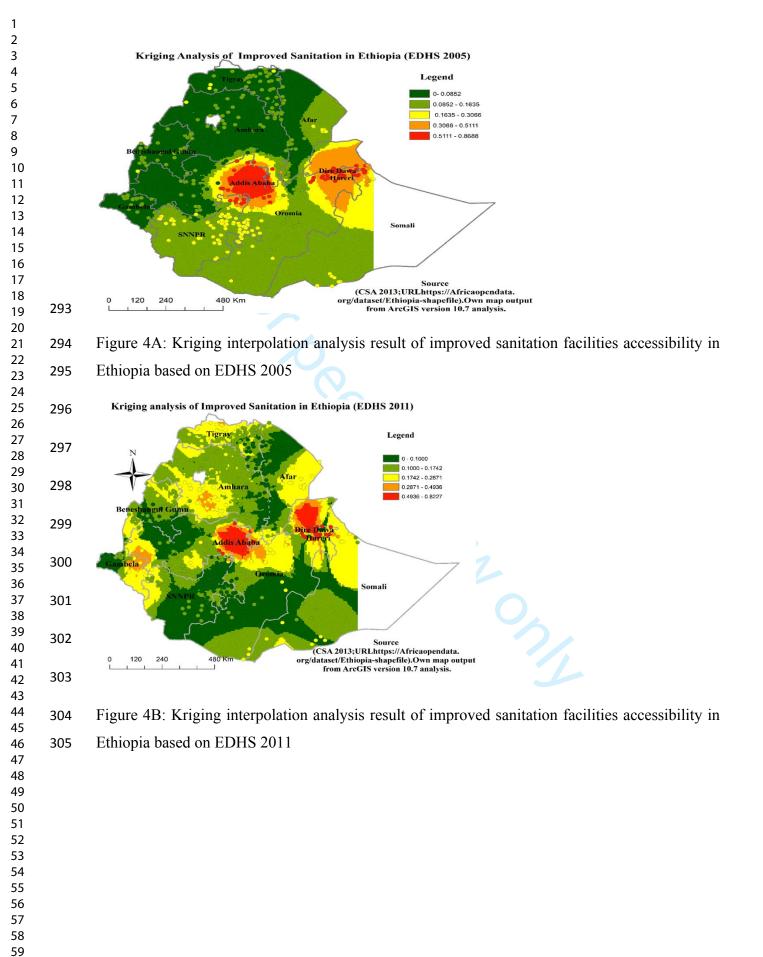
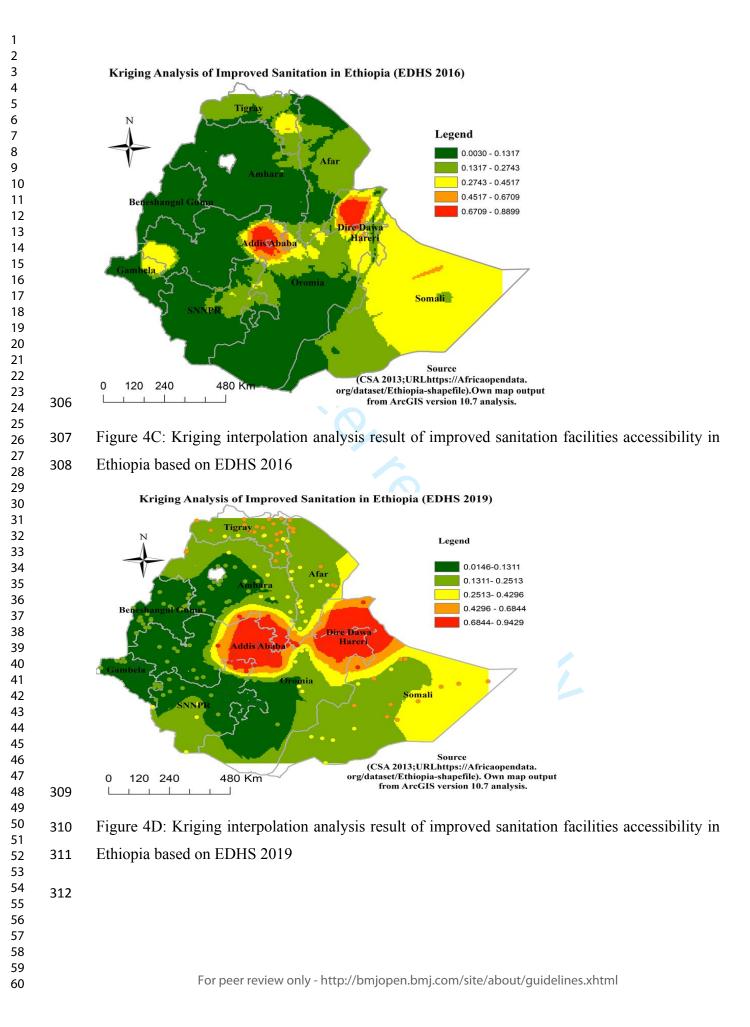


Figure 3D: Hot and cold spot analysis of accessibility of improved sanitation facilities in Ethiopia
based on the dataset of EDHS 2019

287 Spatial interpolation

For the identification part of the country which regions experienced lower improved sanitation accessibility, the spatial kriging interpolation analysis was done. The figures below showed that the red color represents part of the country (Addis Ababa and Dre Dawa) with higher in accessing improved sanitation facilities and on the other hand, the green color (major part of the country) indicated that regions with lower in accessing improved sanitation facilities (figure 4).





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313 Discussion

The uniqueness of the analyses lies in the comprehensive examination of temporal trends and geographic variations in sanitation facilities using multilevel and spatial analysis techniques applied to Ethiopia's 2005-2019 EDHS datasets. The novel contribution stems from their in-depth exploration of how access to sanitation infrastructure has evolved over time and varied across different regions of Ethiopia, shedding light on previously unexplored patterns and disparities. This research provides valuable insights into the dynamic nature of sanitation provision and identifies areas for targeted interventions to address disparities and improve overall sanitation access in Ethiopia.

Sustainable and equitable accessibility of improved sanitation facilities is used to hygienically separate human excreta from human contact which leads to many communicable diseases [35]. The main aim of this study was to investigate the spatiotemporal variation and factors associated with improved sanitation facilities accessibly in Ethiopia based on four consecutive EDHS datasets. These results showed that EDHS 2005, EDHS 2011, EDHS 2016, and EDHS 2019 the proportions of the households with access to improved sanitation facilities were 20.46%, 25.61%, 25.86%, and 27.45%, respectively. There was an increment of 5.15% from 2005 to 2011 but the increase from 2011 to 2016 was only by 0.25%. Based on these findings, very slow increments have been experienced over time in the improvement of access to improved sanitation facilities in Ethiopia from 2005 to 2019. This result is comparable with previous studies, which indicated that some countries have shown high progress toward SDG 6, while others look to be stuck at low levels of sanitation coverage with little or no development [36]. Such setback with little or no development levels of access to improved sanitation facilities is the experience of developing countries including Ethiopia [37]. The possible explanation for this problem could be due to global environmental change, paying less attention due to poverty, instability of the country related with civil war trauma, which lead less attention, by government and non-governmental organization for sanitation facilities development. This finding consistent with other previous studies done in different parts of the world [26, 38-42].

Results of Global Moran's autocorrelation, hotspot, cluster, and kriging in the spatial analysis
showed that there were great disparities in accessing improved sanitation facilities in Ethiopia
based on four EDHS datasets. Based on the results of hot spot, and kriging analysis in all EDHS
Addis Ababa and dire Dawa were a high hot spot of improved sanitation facilities among other

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parts of the country. This finding put forward that there are significant geographical disparities in access to improved sanitation facilities throughout the country. Which contradicted persistently sustainable development goal 2030 agenda target 6.2 "access to adequate and equitable sanitation for all and end open defecation"[43]. This variation could be the difference in economic growth, overpopulation growth, unplanned urbanization, and inaccessibility of infrastructure, government overload towards other burning daily tasks, socio-political instability, awareness, and adaptability towards sanitation facilities.

Factors associated with access to improved sanitation facilities were the educational status of the household head, having television, and wealth index, in individual-level predictors whereas community-level education, community-level media exposure, type of residence, and region were community-level predictor variables.

In households with a higher educational status, the household head had a greater chance of accessing improved sanitation facilities compared to households with heads who had no education. This finding is supported by the studies done in Ethiopia, Kenya, West and Central Africa, Bangladesh, Benin, and Vietnam [44-47]. The community with higher education accessed improved sanitation facilities than part of the community with lower education. This finding was in line with other previous studies conducted in different parts of the world [20, 48, 49]. The reason for this variation could be that educated individuals might understand the association between health and improved sanitation facilities. If so they are enthusiastic to have these sanitation facilities compared to household heads with lower educational status.

There was a proportional relationship between the levels of wealth status and access to improved sanitation facilities. Rich, and middle households in wealth status were more likely to have access to improved sanitation facilities compared to the poorest households. This finding is supported by the studies done in Ghana, Benin, Vietnam, and Eswatini [45, 50-52]. This difference could be due to the installation of improved sanitation facilities such as septic tanks, pour flush toilet facilities; pit latrines with a slab, and composting toilet facilities might be difficult for the poor to afford them.

Holding other variables constant, households that had television were more likely in accessing
 improved sanitation facilities compared to households with no television. This might probably be
 because inhabitants spent their time watching television which acts as an information source

visually, including the role of improved sanitation in reducing disease transmission. Community-level media exposure was the other community-level factor statistically significant predictor associated with access to improved sanitation facilities. Household members exposed to community-level media (television, radio, or one of the two) had more chances of accessing improved sanitation in Ethiopia. This finding was in line with previous studies conducted in Ethiopia [19, 20], and sub-Saharan Africa [53].

Households found in the urban area more likely to access improved sanitation facilities than those found in the rural area. This issue was Supported by a previous study done in Ethiopia which indicated that rural areas of Ethiopia are extremely lagging late in the race toward realizing SDG 6.2 [36] and the other study done in Vietnam [50]. Households found in different regions of Ethiopia were accessed different proportions of improved sanitation facilities. The capital city Addis Ababa was better than the regions of the country. This finding is aligns with the studies done in Kenya [54], Nepal [55] and WHO, UNICEF, 2019 report [56] which indicated that persist disparities in access to WASH services in rural versus urban settings. The possible explanation, for this difference might be due to Addis Ababa being the capital city of the country and it is the headquarter of the Africa Union more infrastructure including improved sanitation facilities could be fulfilled. In addition, it could be due to low economic status, socio-political instability among regions, lack of awareness, lower adaptability towards sanitation facilities.[57].

The self-report nature of data collection which leads to interviewer bias, social acceptability bias, recall bias and incompleteness of the recent mini demographic health survey (EDHS 2019) could be potential sources of errors and the limitations of this study.

Conclusion

The overall finding of this study concludes that there was a very slow increment of accessibility of sanitation facilities over time in Ethiopia. As well as, there was statistically significant geographical heterogeneity in accessibility of improved sanitation facilities in the country. The rate of current progress in universal access to sanitation facilities (SDG 6.2) in 2030 should be accelerated to reach the proposed plan. Educational status, watching television, wealth index, community-level education, community-level media exposure, type of residence, and region were factors statistically associated with sanitation facilities accessibility in Ethiopia. This finding

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1 2						
2 3 4	403	suggested for international and local organizations work on solutions that enable the progress in				
4 5 6	404	sanitation facilities accessibility for all, especially in developing countries.				
7 8	405	Abbreviations				
9 10	406	AIC: Akaike's Information Criterion, AOR: Adjusted Odds Ratio, CI: Confidence Interval, DHS:				
11 12	407	Demographic and Health Survey, EAs: Enumeration Areas, EDHS: Ethiopian Demographic and				
13 14	408	Health Survey, ICC: Intra Class Correlation, MOR: Median Odd Ratio, PCV: Proportional Change				
14 15 16	409	in Variance				
17 18	410	Declarations				
19	411	Ethics approval and consent to participate				
20 21	412	This study was based on secondary data from the Ethiopian Demographic and Health Survey and				
22 23	413	secured the permission letter from the main Demographic Health and Survey. Permission for data				
24 25	414	access was obtained from a major Demographic and Health Survey through an online request at				
26	415	(https://www.dhsprogram.com/data/dataset_admin/login_main.cfm.). Participant consent was not				
27 28	416	directly obtained since authors used secondary data.				
29 30	417	Consent for publication				
31 32	418	Not applicable.				
33 34	419	Availability of data and materials				
35 36	420	This research was done using a publicly available dataset found at				
37 38	421	https://www.dhsprogram.com/data/dataset_admin/login_main.cfm. after approval from Data				
39 40	422	Archivist of the Demographic and Health Surveys (DHS) Program.				
41 42 43	423	Competing interests				
44 45	424	There is no any competing interest.				
46 47	425	Funding				
48 49	426	There is no specific grant for doing this research.				
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54 55 56 57 58 59 60	429	JA: Formal analysis For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml				

1 2								
3 4	430	JA, MT, WM: Investigation						
5 6 7	431	JA, MT, WM: Methodology						
, 8 9	432	JA, WM: Software						
10 11	433	JA, MT, WM: Validation						
12 13 14	434	JA, MT: Visualization						
15 16	435	JA, WM: Write-up						
17 18 19	436	JA, MT, WM: Review & editing						
20 21	437	All authors read and approved the final manuscript.						
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26 27 28	440	data and shape files for this study.						
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Temporal trends and spatial heterogeneity of sanitation facilities in Ethiopia: evidence from the 2005-2019 Demographic and Health Surveys

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3 4	1	Temporal trends and spatial heterogeneity of sanitation facilities in Ethiopia:
5 6	2	evidence from the 2005-2019 Demographic and Health Surveys
7 8	3	Jember Azanaw ¹ *, Mesenbet Tsegaye ² , Wodaje Mesele ³
9	4	¹ Department of Environmental and Occupational Health and Safety, Institute of Public Health,
10 11	5	College of Medicine and Health Sciences, University of Gondar, Gondar, Ethiopia
12 13	6	² Department of General Surgery, School of Medicine, College of Medicine and Health Sciences,
14	7	University of Gondar, Gondar, Ethiopia
15 16	8	³ Department of Orthopaedic and Trauma Surgeon, School of Medicine, College of Medicine and
17 18	9	Health Sciences, University of Gondar, Gondar, Ethiopia
19	10	
20 21	11	*=Corresponding
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24 25	12	jemberazanaw21@gmail.com
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26 Abstract

Background: The main aim of sanitation is to prevent human contact with fecal pathogens to
decrease occurrences of diseases. But, no region in the world is on the right track to accomplish
Sustanaible development goal (SDG) 6.2 for universal access to sanitation. Sub-Sahara Africa,
Ethiopia included, is significantly behind in meeting the 2030 SDG 6.2 targets. Hence, this study
focused on the spatial and temporal analysis of sanitation in Ethiopia based on four demographic
health surveys.

Method: This research was undertaken among households in Ethiopia based on a weighted sample size. Variables with a p-value below 0.2 in bivariable analysis were incorporated into the multivariable analysis. Subsequently, a 95% CI and a p-value < 0.05 were utilized to assess the statistical significance of the final model. Global and local indicators of spatial correlation were done. Statistical analyses were performed using STATA 17, and ArcGIS 10.7 software.

Results: This study includes 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in 2019 EDHS 8,663 households. The prevalence of improved sanitation facilities in Ethiopia was 20.46%, 25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively. Global Moran's I spatial autocorrelations, hotspots, and spatial interpolation analysis indicated the inequality of improved sanitation facilities. Educational status of primary (AOR = 2.43, 95% CI : 2.00, 2.95), secondary (AOR = 2.02, 95% CI : 1.61, 2.54), and higher (AOR = 4.12, 95% CI :3.35, 7.54), watching television (AOR= 5.49, 95% CI: 4.37, 6.89), urban areas (AOR= 9.08, 95% CI: 6.69, 12.33), and region were factors statistically associated with sanitation facilities.

47 Conclusion: The overall finding of this study concludes a very slow increment in sanitation
48 facilities over time and presence of geographical heterogeneity in Ethiopia. Educational status,
49 watching television, wealth index, community-level education, type of residence, and region were
50 factors statistically associated with sanitation facilities.

51 Keywords: EDHS, Ethiopia, Improved Sanitation, Spatiotemporal variation

54 Background

 Sanitation refers to the endowment of services and facilities for the safe and clean controlling of
human excreta, from the toilet to handling and containment to the final end-use or removal [1].
Sanitation is an integral component of basic human rights comparable to food, shelter, and water
and is vital for healthy life [2].

According to the United Nations (UN-2018) report, in the world, around 4.5 billion people had no safe sanitation sand 892 million continue to practice Open Defecation (OD) [3, 4]. Inadequate access to sanitation is a principal reason for poverty in unindustrialized nations because it causes early mortality [5, 6]. According to World Health Organization (WHO) 2019 estimation, drinking water sources of two billion people were contaminated with feces and over 800,000 people die annually from diarrhea caused by poor water, sanitation, and hygiene (WASH) (World Health Organization, 2019). Internationally, sanitation sector are expected to be impacted by climate change, changing precipitation patterns, rapid urbanization, lack of context-specific and pragmatic advice on adaptation measures for sanitation service providers [7-9]. In Eastern and Southern Africa, 340 million people (more than 70%) have no access to basic sanitation services, 98 million people (19 percent) practice open defecation, 179 million use unimproved facilities, and 63 million shared sanitation facilities [10].

Due to such problems, Sustainable Development Goals (SDGs 6.2) stand to ensure accessibility of equitable sanitation for all by the year 2030 [11]. SDG 6.2 of the United Nations, which emanated in 2015 from the Millennium Development Goals, aims at equitable access to safe and affordable sanitation for all by 2030 (10). The main aim of this SDG is to prevent human contact with fecal pathogens to decrease occurrences of diseases [12, 13]. Nevertheless, no region in the world is on the right track to accomplish SDG 6.2 for universal access to sanitation, and urban sewer connections are increasing at an embarrassingly slow rate of 0.14% annually [14]. Especially, countries in Sub-Saharan Africa (SSA) countries are extremely late to achieve SDG 6.2 2030 agenda due to the rapid population growth rate, without enough investment in sanitation infrastructures [15, 16]. At the same time, inequalities in accessing sanitation facilities were more pronounced among countries in sub-Saharan Africa [17]. There is a disparity within countries, mainly regarding urban and rural residences, which indicated that rural inhabitants access markedly lower levels of sanitation than with urban residences [18]. Such Subnational variation in

access to improved sanitation facilities, defined as the range of values from the unit with the
highest level of access to the unit with the lowest level or no access, are evident across low and
middle income countries [19]. Like other developing countries [20] access to sanitation is a
challenge across Ethiopia [21], as well as there are disparities among the regions of the country.
On the other hand, nations may strengthen or setback the progress of equitable access to improved
sanitation facilities.

Previous studies in Ethiopia were based on a single EDHS or only multilevel analysis or spatial analysis in order to investigate improved sanitation facilities [22]. Such studies unable to show the trend of improved sanitation facilities progress overtime. Residence, educational attainment, watching television, household size, region, and wealth index are factors associated with the improved sanitation source as in previous studies [23-25]. Hence, this study focused on the spatial and temporal analysis of sanitation facilities in Ethiopia based on combined multiple (2005, 2010, 2016, and 2019) demographic health surveys for better understanding of the progress and geographic variation within the country.

98 Methods

99 Study area and Data source

This study was conducted in Ethiopia, which is nine geographical regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples Region (SNNPR), Gambella, and Harari), and two administrative cities (Addis Ababa and Dire-Dawa) of the country. The country is located in the Horn of Africa with geographical locations 9.145° N latitude and 40.4897° East longitude [26]. This study used the four successive Ethiopian Demographic and Health Surveys (EDHS 2005, 2011, 2016, and 2019) database survey. Therefore, these are nationally representative population-based surveys with large sample sizes at different times. EDHS data is open source and can be retrieved on the DHS website https://www.dhsprogram.com/data/dataset admin/login main.cfm.

All EDHS samples were a two-stage stratified cluster sample [27], sampling weights were calculated based on sampling probabilities separately for each sampling stage and each cluster. In 2005 surveys, 540 enumeration areas (EAs) (139 urban and 401 rural areas) [28], 2011 EDHS, 624 EAs (187 urban and 437 rural areas) [29], 2016 EDHS 645 EAs (202 in urban areas and 443 in

rural areas) [30], and 2019 EDHS 305 EAs (93 in urban areas and 212 in rural areas) [31]were selected using systematic sampling with likelihood proportional to size.

In the second stage of selection, a fixed number of 30 households per cluster were selected with an equal probability of systematic selection from the newly created household listing. The field practice was conducted in Adama in clusters that were not part of the survey sample. Ethiopian public health institute investigators, an ICF technical specialist, an advisor, and representatives from other organizations, including central statistics agency, the Federal Ministry of Health, the World Bank, and USAID, supported the data collection in this EDHS data collection [28].

Among included households, 13,721, 16,702, 16, 650, and 8,663 were successfully interviewed in EDHS 2005, 2011, 2016, and 2019, respectively [28, 30]. Weighted by sampling weight was done to do a reliable statistical analysis. The geographical location data were taken from selected respective Enumeration Areas (EAs).

Study Variables

Outcome variables

The dependent variable was the sanitation facilities. The sanitation type categorized as '1' on behalf of 'improved sanitation' which accessed from flush/pour flush to piped sewer systems, septic tanks, or pit latrines; ventilated improved pit latrines, composting toilets or pit latrines with slabs, and '0' for 'unimproved sanitation' when the sanitation facilities from pit latrines without a slab or platform, hanging latrines or bucket latrines and open defecation [32-34].

Predictor variables

Individual level variables: sex of household head (male or female), wealth index (poor, middle, and rich), educational status (no education, primary education, secondary education, and higher education), having a television (yes or no) and radio (yes or no) were individual-level predictor variables.

Community level variables: Community level education (lower/higher), the place of residence (urban/rural), community level media exposure (exposed/unexposed), region (Benishangul-Gumuz, Somali, Gambella, Afar, Oromia, SNNPR, Amhara, Tigray, and Harari) and City administration (Addis Ababa, and Dire Dawa).

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141 Data management and analysis

For data quality assurance purposes, pretests containing in-class training, biomarker training, and field exercise were done. The field exercise was conducted in clusters, which were not included in the EDHS sample. A debriefing session was held with the pretest field staff, and adjustments to the questionnaires were done based on lessons drawn from the field practice. Since the outcome variables were dichotomous, logistic regression analysis was conducted to assess associations of outcome variables and predictor variables. Variables in bivariable analysis with a p-value less than 0.2 were included in multivariable binary logistic regression analysis. 95% confidence interval (CI) and a p-value less than 0.05 were used for identifying statistical significance in the final model [35].

151 Multilevel Analysis

Four models, a null model (model 0) without any predictor variable, model 1 comprised dependent and individual-level predictors, model 2 incorporated dependent and community-level predictors, and model 3 involved all variables from models 1 and 2. Random effects were measured using cluster variance (Vc), a proportional change in variance ((PCV ((Vc - Vn)/Vc)) the intraclass correlation coefficient (ICC(Vc/(Vc + 3.29)), and the median odds ratio (MOR (exp [(0.95) \sqrt{Vc}]))) [36, 37]. The goodness-of-fit for all models was evaluated using AIC, BIC, and Deviance. Then the model with the lower value of deviance, AIC, and BIC, was demonstrating the best-fit model [38]. As well as Multicollinearity, the effect of independent variables was measured using the variance inflation factor (VIF).

161 Spatial analysis

Spatial Autocorrelation

163 To explore the geographical distribution, both global and local indicators of spatial correlation are 164 the best imperative tools for access to improved sanitation facilities within the specified period.

Global autocorrelations

To proceed with geographical variation identification of access to improved sanitation facilities,
Global autocorrelations analysis was done. Global spatial autocorrelation (Moran's I index) was
used to detect whether the difference is due to the clustering effect or non-random/dispersion [39,

40]. As well as the simple exploratory spatial analysis was performed to identify the presence ofimproved sanitation facilities and geographical dependence distribution in the country.

171 Local statistical analysis

Further investigation using figures and maps is needed since Global autocorrelations indicate a clustering effect (positive spatial autocorrelation) on sanitation facilities' access over the country. Therefore, hotspot analysis (Gettis-Ord Gi*) was performed to identify patterns of spatial variation and emphasize the previously stated using global autocorrelations (cluster effect) on access to sanitation facilities. Cluster and outlier analysis (Anselin local Moran is I) was used to describe the spatial patterns of the dependent variables (access to sanitation facilities). This cluster and outlier analysis was used to confirm and accompaniment to show extreme (the hotspot and cold spot) since it permits the identification of groupings and areas where the differences happen [41].

Results

26
 27 181 Socio-demographic characteristics of the study population

This study include 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in 2019 EDHS 8,663 participants. In all EDHS, data sets the greater proportion (63.59%, 55.74%, 52.06%, and 47.65%, respectively) of study subjects were no education. The majority (88.30%, 81.68%, 76.98%, and 77.10%) of the participants in the 2005 EDHS, 16,702the in the 2011 EDHS, 16,650 in the 2016 EDHS, and 2019 EDHS, respectively, had no television (Table 1).

187 Table 1. Socio-demographic characteristics of study Participants in Ethiopia

	1			
Variables	EDHS 2005	EDHS 2011	EDHS 2016 (N=	EDHS 2019 (N=
	(N=13,721)	(N=16,702)	16,650)	8,663)
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Sex of HHH				
Male	10,243(74.65)	11,906(71.28)	11,413(68.55)	6,291(72.62)
Female	3,478(25.35)	4,796 (28.72)	5,237(31.45)	2,372(27.38)
Age of HHH				
<30	3,428(24.98)	4,823(28.88)	4,257(25.57)	2,520(29.09)
30-40	3,501(25.52)	4,116(24.64)	4,132(24.82)	2,287(26.40)
41-54	3,756(27.37)	4,047(24.23)	4,230(25.41)	1,717(19.82)
>54	3,036(22.13)	3,716(22.25)	4,031(24.21)	2,139(24.69)
Educational status of				
ННН				
No education	8,725(63.59)	9,309(55.74)	8,668(52.06)	4,128(47.65)

Primary	2,705(19.71)	5,020(30.06)	4,658(27.98)	2,715(31.34
Second	1,754(12.78)	1,189(7.12)	1,686(10.12)	963(11.12)
Higher	495(3.61)	1,140(6.83)	1,580(9.49)	857(9.89)
Wealth index				
Poor	5,393(39.30)	6,506(38.95)	7,024(42.19)	3,498(40.38)
Middle	2,055(14.98)	2,364(14.15)	2,057(12.35)	1,285(14.83
Rich	6,273(45.72)	7,832(46.89)	7,569(45.46)	3,880(44.79
Share toilet with other ho	ouseholds			
Yes	2,712(45.72)	4,467(46.12)	4,727(43.83)	2,222 (38.18
No	3,204(54.01)	5,204(53.73)	6,059(56.17)	3,598(61.82)
Having radio				
No	8,157(59.45)	9,658(57.83)	11,680(70.15)	6,170 (71.22
Yes	5,560(40.52)	7,040(42.15)	4,970(29.85)	2,493(28.78)
Having Television			Ì Ì	
No	12,116(88.30)	13,643(81.68)	12,818(76.98)	6,679 (77.10
Yes	1,601(11.67)	3,051(18.27)	3,832(23.02)	1,984(22.90)
Community-level media				
exposure	0.105(50.07)	0.072(52.72)	10.024((0.20)	5 105(50.07)
Unexposed	8,105(59.07)	8,973(53.72)	10,024(60.20)	5,195(59.97)
Exposed	5,616(40.93)	7,729(46.28)	6,626(39.80)	3,468(40.03)
Community-level				
educational status		0.200(55.74)	0.70((50.41)	4 200(40 72)
Lower	8,730(63.63)	9,309(55.74)	8,726(52.41)	4,308(49.73)
Higher	4,991(36.37)	7,393(44.26)	7,924(47.59)	4,355(50.27)
Residence		5 112 (20 (1)	5.000(01.40)	
Urban	3,666(26.72)	5,112(30.61)	5,232(31.42)	2,645(30.53
Rural	10,055(73.28)	11,590(69.39)	11,418(68.58)	6,018(69.47
Region				
Tigray	1,282(9.34)	1,730(10.36)	1,734(10.41)	714(8.24
Afar	806(5.87)	1,267(7.59)	1,220(7.33)	664 (7.66)
Amhara	2,066(15.06)	2,071(12.40)	1,902(11.42)	1,007(11.62)
Oromia	2,155(15.71)	2,165(12.96)	1,988(11.94)	1,018(11.75
Somali	796(5.80)	975(5.84)	1,564(9.39)	657(7.58)
Benishangul-Gumuz	869(6.33)	1,323(7.92)	1,280(7.69)	734(8.47)
SNNPR	1,933(14.09)	2,045(12.24)	1,897(11.39)	1,017(11.74
Gambella	820(5.98)	1,215(7.27)	1,280(7.69)	693(8.00)
Harari	904(6.59)	1,201(7.19)	1,135(6.82)	719(8.30)
Addis Ababa	1,333(9.72)	1,524(9.12)	1,489(8.94)	702(8.10)
Dire Dawa	757(5.52)	1,186(7.10)	1,161(6.97)	738(8.52)

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1). education. the media.

192 Trends of Sanitation facilities in Ethiopia

Figure 1 below presented that the trend of improved sanitation facilities in Ethiopia was 20.46%,
25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively (figure
1).

196 Factors Associated with Sanitation Facilities Accessibility

The odds of accessibility to improved sanitation facilities among participants with educational status of primary, secondary, and higher were 2.43 (AOR = 2.43, 95% CI :(2.00, 2.95)), 2.02 (AOR = 2.02, 95% CI :(1.61, 2.54)), and 4.12 (AOR = 4.12, 95% CI :(3.35, 7.54) times more likely respectively, compared to those with no education.

201 Study participants with wealth status of the middle, and rich were 1.49 (AOR = 1.49, 95% CI : (202 1.21, 1.83)), and 3.15 (AOR = 3.15, 95% CI : (2.55, 3.89)) times more likely in the odds of 203 accessing improved sanitation facilities respectively, compared to those counterparts poor.

- 204 The odds of accessing improved sanitation facilities among study participants watched television
 205 were 5.49 (AOR= 5.49, 95% CI: (4.37, 6.89)) more likely compared to counterparts who did no
 206 watching television.
- Community-level education was a statistically significant predictor variable. The odds of accessing improved sanitation facilities among Communities with higher educational levels were 3.90 (AOR= 3.90, 95% CI: (3.15, 4.82) times more likely compared to the community with lower education.

The chance of accessing improved sanitation facilities among communities exposed to media was 5.61 (AOR= 5.61, 95% CI: (3.84, 10.09)) times more likely than in the community unexposed to the media.

- The odds of accessibility-improved sanitation facilities among the study population living in urban areas were 9.08 (AOR= 9.08, 95% CI: (6.69, 12.33) times more likely compared to the o study population living in rural areas.
- 217 Communities across various regions, including Tigray (54% less likely, AOR=0.46; 95% CI: 0.37,
- ²⁴ 218 0.57), Afar (33% less likely, AOR=0.67; 95% CI: 0.51, 0.86), Somali (77% less likely, AOR=0.23;
- ⁵⁶ 219 95% CI: 0.18, 0.29), Amhara (60% less likely, AOR=0.40; 95% CI: 0.32, 0.49), Benishangul

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Gumuz (37% less likely, AOR=0.63; 95% CI: 0.49, 0.80), Gambella (55% less likely, AOR=0.45; 95% CI: 0.35, 0.57), Harari (36% less likely, AOR=0.64; 95% CI: 0.52, 0.80), SNNRP (72% less likely, AOR=0.28; 95% CI: 0.22, 0.34), and Dire Dawa (72% less likely, AOR=0.28; 95% CI: 0.22, 0.35), exhibit decreased access to improved sanitation facilities compared to communities in Addis Ababa.

The random variations of sanitation were demonstrated by intra-cluster correlation coefficient (ICC), Proportion Change in Variance (PCV), and median odds ratio (MOR). The ICC in the null model showed that 67.65% of the total variability in accessing improved sanitation facilities was due to differences through cluster areas. Model 1 and Model 2 presented that 59.74% and 26.35% of the Proportion Change in Variance (PCV) of the variation in accessing improved sanitation in the communities was explained by individual and community-level factors, respectively. The MOR between the area at highest in accessing improved sanitation facilities and the area at lowest in accessing improved sanitation facilities if randomly picking out two areas was 7.07.

The goodness fit in model statistics indicated using the lowest values of AIC, DIC, and Deviance.
Therefore, the final model had the lowest AIC, DIC, and Deviance, 11151.08, 11282.33, and
11,117.0824, respectively which confirmed the best-fit model (Table 2 and Table 3)

Table 2. Multilevel binary logistic regression analysis of predictors towards accessibility ofsanitation facilities in Ethiopia, EDHS 2011

Variables	Model 0	Model 1	Model 2	Model 3
	(Null	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
	model)			
Individual leve	l Factors			
Sex of HHH				
Male		0.97(0.82,1.04)		1.01(0.84,1.11)
Female		1	1	1
Age of HHH	·		·	· · ·
<30		0.97(0.94,1.01)		0.96 (0.20,2.34)
30-40		0.57(0.35,2.02)		1.49(0.13,2.41)
41-54		0.43(0.22,0.61)		1.17(0.86,1.59)
>54		1	1	1
Educational stat	tus			·
No education		1		1
Primary		3.23 (2.63,3.96)**		2.43(2.00,2.95)**
Secondary		6.36(5.26,7.67)**		2.02(1.61,2.54)**

Wealth index Poor Middle Rich			4.12(3.35,7.54)**
Middle			
	1		1
Rich	2.96 (2.34,4.24)**		1.49 (1.21,1.83)*
	5.48 (3.45,5.89)**		3.15(2.55,3.89)**
Having television			
No	1		1
Yes	4.81(4.16,5.56)**		5.49(4.37,6.89)*
Community level fac	tors		
Community level edu	cation		
Higher		6.50(5.82,7.27)**	3.90(3.15,4.82)**
Lower		1	1
Community-level me	dia exposure		
Exposed		6.07(5.42,6.81)**	5.61(3.84,10.09)*
Unexposed		1	1
Type of residence			
Urban		16.74(11.85, 23.65)**	9.08(6.69,12.33)*
Rural		1	1
Region			
Tigray		0.50(0.41,0.62)**	0.46(0.37,0.57)**
Afar		0.86(0.67,1.09)	0.67(0.51,0.86)*
Amhara	(0.43(0.35,0.53)**	0.40(0.32,0.49)**
Oromia		0.89 (0.72,1.09)	0.90(0.73,1.12)
SNNRP		0.25(0.20,0.31)*	0.28(0.22,0.34)**
Somali		0.33(0.26,0.41)**	0.23(0.18,0.29)**
Benishangul		0.74(0.59,0.94)*	0.63(0.49,0.80)**
Gumuz			
Gambella		0.51(0.41,0.64)**	0.45(0.35,0.57)**
Harari			0.64(0.52.0.80)**
Addis Ababa		1	1
Dire Dawa		0.25(0.21,0.31)**	0.28(0.22,0.35)**
VIF	2.35	2.27	2.05

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240	Table 3: Measures variation metrics and the model fitness test statistics used for included me	odels	
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Metrics	Model 0 (Null model)	Model 1	Variables	Model 0 (Null model)
Variance	6.88(5.84,8.10)	2.77(2.30,3.32)	2.04(1.71,2.44)	1.97(1.65,2.35)
MOR	7.07	4.35	3.82	3.78
PCV	Reference	59.74%	26.35%	3.43 %
ICC	0.6765	0.4571	0.3827	0.3745
Model fitness test sta	tistics			
AIC	12204.07	11338.86	11610.79	11151.08
BIC	12219.51	11454.67	11734.32	11282.33
Deviance	12,200.0736	11,323.6174	11611.497	11,117.0824

242 Analysis of spatial heterogeneity

243 Spatial autocorrelation (Moran's I)

Global Moran's I spatial autocorrelations positive z-scores (with the z-scores of 2005 EDHS
2.374393,2011 EDHS 7.067996, 2016 EDHS 8.9374285, and 2019 EDHS 36.511348) indicated
that all EDHS were clustered in accessing improved sanitation facilities through Ethiopia (Figure
247 2).

248 Hot and cold spot analysis (Getis-Ord Gi*)

Hot and cold spot analysis revealed that there was the same trend in spatial distribution of improved sanitation facilities through Ethiopia in all EDHS. The figures below show that in all EDHS the percentage of accessing improved sanitation was significantly lower in most parts of the country while this proportion was better only in Addis Ababa, and Dire Dawa (Figure 3).

253 Spatial interpolation

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For the identification part of the country which regions experienced lower improved sanitation accessibility, the spatial Kriging interpolation analysis was done. The figures below showed that the red color represents part of the country (Addis Ababa and Dire Dawa) with higher in accessing improved sanitation facilities and on the other hand, the green color (major part of the country) indicated that regions with lower in accessing improved sanitation facilities (figure 4).

260 Discussion

The uniqueness of the analyses lies in the comprehensive examination of temporal trends and geographic variations in sanitation facilities using multilevel and spatial analysis techniques applied to Ethiopia's 2005-2019 EDHS datasets. The novel contribution stems from their in-depth exploration of how access to sanitation infrastructure has evolved over time and varied across different regions of Ethiopia, shedding light on previously unexplored patterns and disparities. This research provides valuable insights into the dynamic nature of sanitation provision and identifies areas for targeted interventions to address disparities and improve overall sanitation access in Ethiopia.

Sustainable and equitable accessibility of improved sanitation facilities is used to hygienically separate human excreta from human contact which leads to many communicable diseases [42]. The main aim of this study was to investigate the spatiotemporal variation and factors associated with improved sanitation facilities accessibly in Ethiopia based on four consecutive EDHS datasets. These results showed that EDHS 2005, EDHS 2011, EDHS 2016, and EDHS 2019 the proportions of the households with access to improved sanitation facilities were 20.46%, 25.61%, 25.86%, and 27.45%, respectively. There was an increment of 5.15% from 2005 to 2011 but the increase from 2011 to 2016 was only by 0.25%. Based on these findings, very slow increments have been experienced over time in the improvement of access to improved sanitation facilities in Ethiopia from 2005 to 2019. This result is comparable with previous studies, which indicated that some countries have shown high progress toward SDG 6, while others look to be stuck at low levels of sanitation coverage with little or no development [43]. Such setback with little or no development levels of access to improved sanitation facilities is the experience of developing countries including Ethiopia [44]. The possible explanation for this problem could be due to global environmental change, paying less attention due to poverty, instability of the country related with civil war trauma, which lead less attention, by government and non-governmental organization for sanitation facilities development. This finding consistent with other previous studies done in different parts of the world [33, 45-49].

Results of Global Moran's autocorrelation, hotspot, cluster, and Kriging in the spatial analysis
showed that there were great disparities in accessing improved sanitation facilities in Ethiopia
based on four EDHS datasets. Based on the results of hot spot, and Kriging analysis in all EDHS
Addis Ababa and dire Dawa were a high hot spot of improved sanitation facilities among other

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parts of the country. This finding put forward that there are significant geographical disparities in
access to improved sanitation facilities throughout the country. Which contradicted persistently
sustainable development goal 2030 agenda target 6.2 "access to adequate and equitable sanitation
for all and end open defecation"[50]. This variation could be the difference in economic growth,
overpopulation growth, unplanned urbanization, and inaccessibility of infrastructure, government
overload towards other burning daily tasks, socio-political instability, awareness, and adaptability
towards sanitation facilities.

Factors associated with access to improved sanitation facilities were the educational status of the household head, having television, and wealth index, in individual-level predictors whereas community-level education, community-level media exposure, type of residence, and region were community-level predictor variables.

In households with a higher educational status, the household head had a greater chance of accessing improved sanitation facilities compared to households with heads who had no education. This finding is supported by the studies done in Ethiopia, Kenya, West and Central Africa, Bangladesh, Benin, and Vietnam [51-54]. The community with higher education accessed improved sanitation facilities than part of the community with lower education. This finding was in line with other previous studies conducted in different parts of the world [23, 55, 56]. The reason for this variation could be that educated individuals might understand the association between health and improved sanitation facilities. If so, they are enthusiastic to have these sanitation facilities compared to household heads with lower educational status.

There was a proportional relationship between the levels of wealth status and access to improved sanitation facilities. Rich and middle households in wealth status were more likely to have access to improved sanitation facilities compared to the poorest households. This finding is supported by the studies done in Ghana, Benin, Vietnam, and Eswatini [52, 57-59]. This difference could be due to the installation of improved sanitation facilities such as septic tanks, pour flush toilet facilities; pit latrines with a slab, and composting toilet facilities might be difficult for the poor to afford them.

Holding other variables constant, households that had television were more likely in accessing
 improved sanitation facilities compared to households with no television. This might probably be
 because inhabitants spent their time watching television, which acts as an information source

visually, including the role of improved sanitation in reducing disease transmission. Community-level media exposure was the other community-level factor statistically significant predictor associated with access to improved sanitation facilities. Household members exposed to community-level media (television, radio, or one of the two) had more chances of accessing improved sanitation in Ethiopia. This finding was in line with previous studies conducted in Ethiopia [22, 23], and sub-Saharan Africa [60].

Households found in the urban area more likely to access improved sanitation facilities than those found in the rural area. This issue was Supported by a previous study done in Ethiopia which indicated that rural areas of Ethiopia are extremely lagging late in the race toward realizing SDG 6.2 [43] and the other study done in Vietnam [57]. Households found in different regions of Ethiopia were accessed different proportions of improved sanitation facilities. The capital city Addis Ababa was better than the regions of the country. This finding is aligns with the studies done in Kenya [61], Nepal [62] and WHO, UNICEF, 2019 report [63] which indicated that persist disparities in access to WASH services in rural versus urban settings. The possible explanation, for this difference might be due to Addis Ababa being the capital city of the country and it is the headquarter of the Africa Union more infrastructure including improved sanitation facilities could be fulfilled. In addition, it could be due to low economic status, socio-political instability among regions, lack of awareness, lower adaptability towards sanitation facilities.[64].

The self-report nature of data collection which leads to interviewer bias, social acceptability bias, recall bias and incompleteness of the recent mini demographic health survey (EDHS 2019) could be potential sources of errors and the limitations of this study.

Conclusion

The overall finding of this study concludes that there was a very slow increment of accessibility of sanitation facilities over time in Ethiopia. As well as, there was statistically significant geographical heterogeneity in accessibility of improved sanitation facilities in the country. The rate of current progress in universal access to sanitation facilities (SDG 6.2) in 2030 should be accelerated to reach the proposed plan. Educational status, watching television, wealth index, community-level education, community-level media exposure, type of residence, and region were factors statistically associated with sanitation facilities accessibility in Ethiopia. This finding

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1 2		
3 4 5 6	350	suggested for international and local organizations work on solutions that enable the progress in
	351	sanitation facilities accessibility for all, especially in developing countries.
7 8	352	Strengths and Limitations of this study
9 10 11 12 13 14 15 16	353	The first strength is using multi EDHS data, which enable to show trend analysis of sanitation
	354	status in Ethiopia.
	355	The second strength is using data from multiple Demographic and Health Surveys ensures a large,
	356	nationally representative sample, which increases the generalizability of findings across Ethiopia.
17 18 19	357	The third strength, DHS surveys provide detailed information on the types of sanitation facilities,
20	358	from basic to improved, which allows for a significance understanding of the sanitation
21 22	359	countryside in Ethiopia.
23 24	360	The first limitation, there could be social desirable bias since the data were collected through face-
25 26 27	361	to-face interview.
27 28 29 30 31 32 33 34 35	362	The second limitation, while the quantitative analysis identifies trends and spatial disparities, it
	363	may not provide insights into the behavioral, and cultural level factors influencing sanitation
	364	adoption and usage.
	365	Abbreviations
36	366	AIC: Akaike's Information Criterion, AOR: Adjusted Odds Ratio, CI: Confidence Interval, DHS:
37 38	367	Demographic and Health Survey, EAs: Enumeration Areas, EDHS: Ethiopian Demographic and
39 40	368	Health Survey, ICC: Intra Class Correlation, MOR: Median Odd Ratio, PCV: Proportional Change
41 42	369	in Variance
43 44	370	Declarations
45 46	371	Ethics approval and consent to participate
47 48	372	This study was based on secondary data from the Ethiopian Demographic and Health Survey and
49	373	secured the permission letter from the main Demographic Health and Survey. Permission for data
50 51	374	access was obtained from a major Demographic and Health Survey through an online request at
52 53	375	(https://www.dhsprogram.com/data/dataset_admin/login_main.cfm.). Participant consent was not
54	376	directly obtained since authors used secondary data.
55 56	377	
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1 2		
2 3 4	378	Patient and Public Involvement
4 5 6	379	Not applicable.
7 8	380	Consent for publication
9 10	381	Not applicable.
11 12	382	Availability of data and materials
13 14	383	This research was done using a publicly available dataset found at
15 16	384	https://www.dhsprogram.com/data/dataset_admin/login_main.cfm after approval from Data
17 18	385	Archivist of the Demographic and Health Surveys (DHS) Program.
19 20 21	386	Competing interests
22 23	387	There is no any competing interest.
24 25	388	Funding
26 27	389	The authors have not received any specific grant for this research from public, commercial, or not-
28	390	for-profit funding agencies
29 30	391	Authors' contributions
31 32	392	JA Engaged in data curation. JA Conducted the statistical analysis. JA, MT, and WM involved in
33	393	investigation of the study. JA and WM had full access to all the data in the study and take
34 35	394	responsibility for the integrity of the data and the accuracy of the data analysis. JA, MT, and WM
36 37	395	done validation and visualization. JA and WM conducted the write-up and drafted the manuscript.
38 39	396	All authors involved in review & editing. JA is responsible for the overall content as guarantors.
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44 45 46	399	data and shape files for this study.
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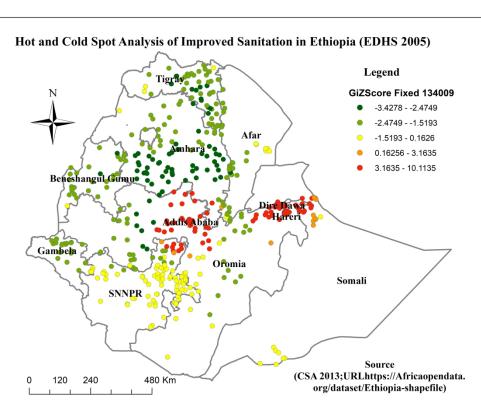
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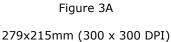
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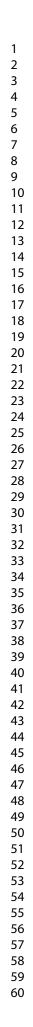


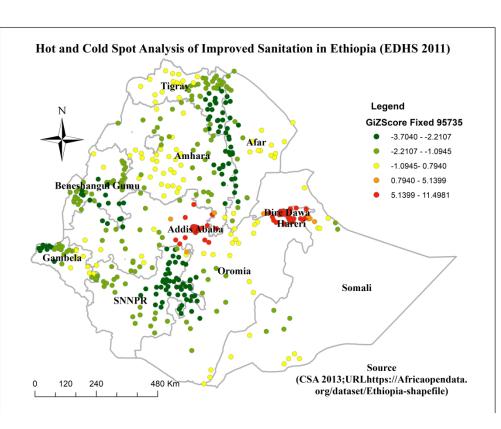


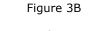
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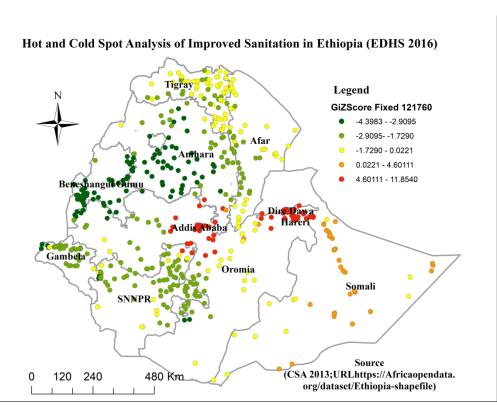
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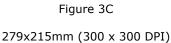




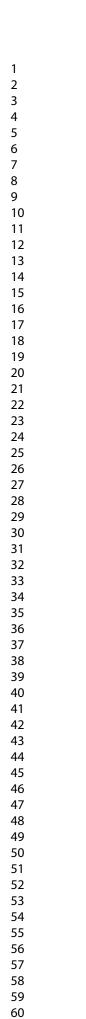


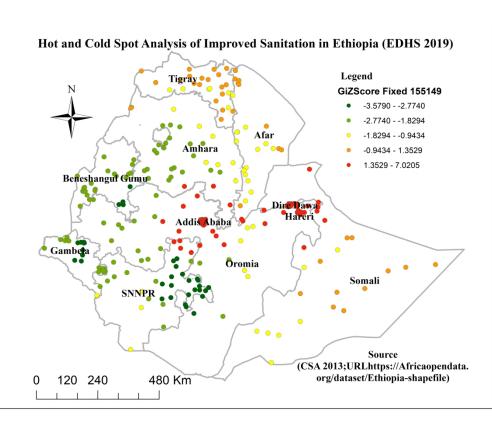
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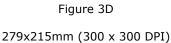


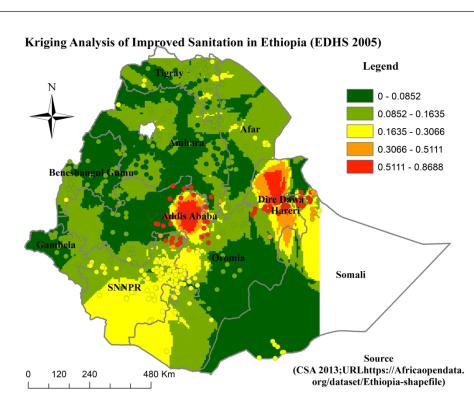


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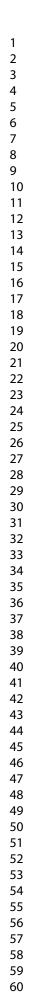


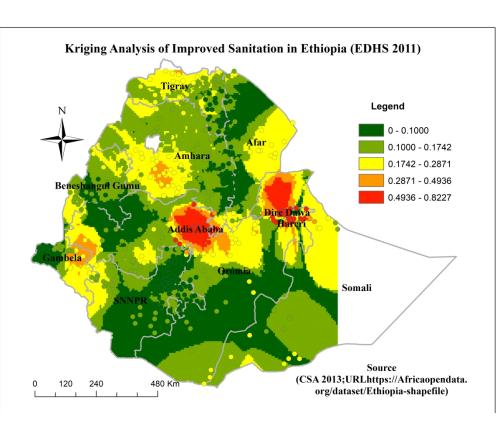




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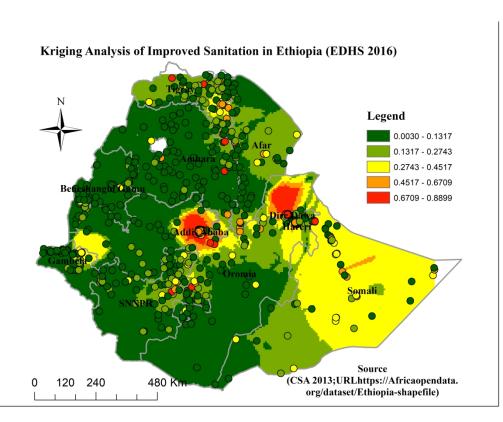
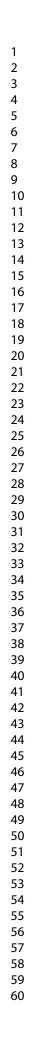
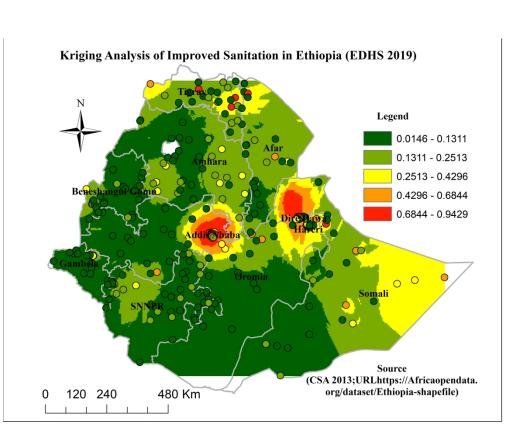
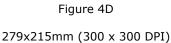


Figure 4C 279x215mm (300 x 300 DPI)







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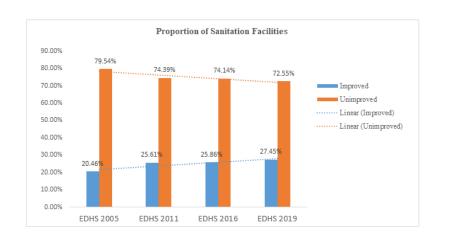
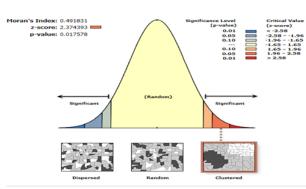


Figure 1

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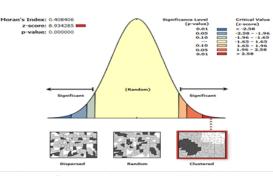
Given the z-score of 2.37439300313, there is a less than 5% likelihood that this clustered pattern could be the result of random chance.

Figure 2A

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Given the z-score of 8.93428534383, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Figure 2B

216x121mm (96 x 96 DPI)

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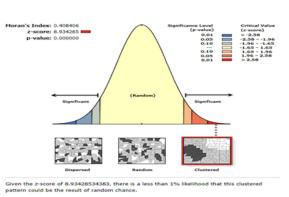
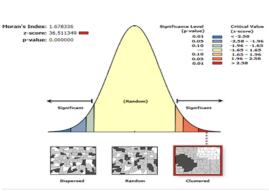


Figure 2C

216x121mm (96 x 96 DPI)



Given the z-score of 36.5113487033, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Figure 2D

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Temporal trends and spatial heterogeneity of sanitation facilities in Ethiopia: evidence from the 2005-2019 Demographic and Health Surveys

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	BMJ Open	Page 2 of 3
1	Temporal trends and spatial heterogeneity of sanitation facilities in Ethiopia:	
2	evidence from the 2005-2019 Demographic and Health Surveys	
3	Jember Azanaw ¹ *, Mesenbet Tsegaye ² , Wodaje Mesele ³	
4	¹ Department of Environmental and Occupational Health and Safety, Institute of Public Health,	
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6	² Department of General Surgery, School of Medicine, College of Medicine and Health Sciences,	lecte
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	For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	S) . ning, Al training, and similar technologies.

Abstract **Background:** The main aim of sanitation is to prevent human contact with fecal pathogens to decrease occurrences of diseases. However, no region in the world is on the right track to accomplish Sustainable development goal (SDG) 6.2 for universal access to sanitation. Sub-Sahara Africa, Ethiopia included, is significantly behind in meeting the 2030 SDG 6.2 targets. Hence, this study focused on the spatial and temporal analysis of sanitation in Ethiopia based on four demographic health surveys. **Method:** This research was undertaken among households in Ethiopia based on a weighted sample size. Variables with a p-value below 0.2 in bivariable analysis were incorporated into the multivariable analysis. Subsequently, a 95% CI and a p-value < 0.05 were utilized to assess the statistical significance of the final model. Global and local indicators of spatial correlation were done. Statistical analyses were performed using STATA 17, and ArcGIS 10.7 software. **Results:** This study includes 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS,

and in 2019 EDHS 8,663 households. The prevalence of improved sanitation facilities in Ethiopia was 20.46%, 25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively. Global Moran's I spatial autocorrelations, hotspots, and spatial interpolation analysis indicated the inequality of improved sanitation facilities. Educational status of primary (AOR = 2.43, 95% CI : 2.00, 2.95), secondary (AOR = 2.02, 95% CI : 1.61, 2.54), and higher (AOR = 4.12, 95% CI :3.35, 7.54), watching television (AOR= 5.49, 95% CI: 4.37, 6.89), urban areas (AOR= 9.08, 95% CI: 6.69, 12.33), and region were factors statistically associated with sanitation facilities.

47 Conclusion: The overall finding of this study concludes a very slow increment in sanitation
48 facilities over time and presence of geographical heterogeneity in Ethiopia. Educational status,
49 watching television, wealth index, community-level education, type of residence, and region were
50 factors statistically associated with sanitation facilities.

51 Keywords: EDHS, Ethiopia, Improved Sanitation, Spatiotemporal variation

Sanitation refers to the endowment of services and facilities for the safe and clean controlling of
human excreta, from the toilet to handling and containment to the final end-use or removal [1].
Sanitation is an integral component of basic human rights comparable to food, shelter, and water
and is vital for healthy life [2].

According to the United Nations (UN-2018) report, in the world, around 4.5 billion people had no safe sanitation sand 892 million continue to practice Open Defecation (OD) [3, 4]. Inadequate access to sanitation is a principal reason for poverty in unindustrialized nations because it causes early mortality [5, 6]. The World Health Organization (WHO) estimated in 2019 that over 800,000 people die each vear from diarrhea brought on by inadequate water, sanitation, and hygiene (WASH), and that two billion people's drinking water sources were tainted with excrement. Climate change, shifting precipitation patterns, increasing urbanization, and a dearth of practical, context-specific guidance on adaption strategies for sanitation service providers are all predicted to have an influence on the sanitation sector globally [7-9]. Over 70% of the population in Eastern and Southern Africa—340 million people—do not have access to basic sanitation services, while 19% defecate in the open, 179 million use unimproved facilities, and 63 million utilize shared sanitation facilities [10].

The Sustainable Development Goals (SDGs 6.2) aim to guarantee universal access to fair sanitation by 2030 as a result of these issues [11]. SDG 6.2 of the United Nations, which emanated in 2015 from the Millennium Development Goals, aims at equitable access to safe and affordable sanitation for all by 2030 (10). The main aim of this SDG is to prevent human contact with fecal pathogens to decrease occurrences of diseases [12, 13]. However, urban sewer connections are growing at an embarrassingly slow rate of 0.14% per year, and no place in the world is on track to achieve SDG 6.2 for universal access to sanitation [14]. Sub-Saharan African (SSA) nations, in particular, are well behind schedule in achieving SDG 6.2 of the 2030 agenda because of their fast population expansion and inadequate investment in sanitary infrastructure [15, 16]. At the same time, disparities in sub-Saharan African nations' access to sanitary facilities were more noticeable [17]. There are differences between nations, primarily in terms of urban and rural housing, which showed that people in rural areas had far worse access to sanitation than people in urban areas [18]. Low and middle-income nations exhibit this subnational variance in access to improved

sanitation facilities, which is defined as the range of values from the unit with the highest level of
access to the unit with the lowest level of access or no access at all [19]. Like other developing
countries [20] access to sanitation is a challenge across Ethiopia [21], as well as there are
disparities among the regions of the country. However, countries have the power to either advance
or impede the development of fair access to better sanitary facilities.

Previous studies in Ethiopia were based on a single EDHS or only multilevel analysis or spatial analysis in order to investigate improved sanitation facilities [22]. These researches are unable to demonstrate the trend of better sanitary facilities over time. As in earlier research, the enhanced sanitation source is linked to residence, educational achievement, television viewing, household size, region, and wealth index [23-25]. In order to better understand the progress and geographic variance within Ethiopia, this study concentrated on the spatial and temporal analysis of sanitation facilities based on a combination of different demographic health surveys conducted in 2005, 2010, 2016, and 2019.

97 Methods

98 Study area and Data source

The study was carried out in Ethiopia, which consists of two administrative cities (Addis Ababa and Dire-Dawa) and nine geographical regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples Region (SNNPR), Gambella, and Harari). The nation is situated in the Horn of Africa, with coordinates of 40.4897° East longitude and 9.145° North latitude [26]. The four consecutive Ethiopian Demographic and Health Surveys (EDHS 2005, 2011, 2016, and 2019) database survey were used in this investigation. These are therefore population-based surveys that are nationally representative and have sizable sample sizes at various points in time.

The DHS website, <u>https://www.dhsprogram.com/data/dataset_admin/login_main.cfm</u>, provides
 access to open source EDHS data.

All EDHS samples were a two-stage stratified cluster sample [27], sampling weights were calculated based on sampling probabilities separately for each sampling stage and each cluster. In 2005 surveys, 540 enumeration areas (EAs) (139 urban and 401 rural areas) [28], 2011 EDHS, 624 EAs (187 urban and 437 rural areas) [29], 2016 EDHS 645 EAs (202 in urban areas and 443 in

rural areas) [30], and 2019 EDHS 305 EAs (93 in urban areas and 212 in rural areas) [31]were selected using systematic sampling with likelihood proportional to size.

In the second stage of selection, a fixed number of 30 households per cluster were selected with an equal probability of systematic selection from the newly created household listing. The field practice was conducted in Adama in clusters that were not part of the survey sample. Ethiopian public health institute investigators, an ICF technical specialist, an advisor, and representatives from other organizations, including central statistics agency, the Federal Ministry of Health, the World Bank, and USAID, supported the data collection in this EDHS data collection [28].

Among included households, 13,721, 16,702, 16, 650, and 8,663 were successfully interviewed in EDHS 2005, 2011, 2016, and 2019, respectively [28, 30]. Weighted by sampling weight was done to do a reliable statistical analysis. The geographical location data were taken from selected respective Enumeration Areas (EAs).

Study Variables

Outcome variables

The dependent variable was the sanitation facilities. The sanitation type designated as '1' represents 'improved sanitation', which can be accessed through flush/pour flush to piped sewer systems, septic tanks, or pit latrines; ventilated improved pit latrines, composting toilets, or pit latrines with slabs; and '0' represents 'unimproved sanitation' since it includes pit latrines without a platform or slab, hanging latrines or bucket latrines, and open defecation [32-34].

Predictor variables

Individual level variables: sex of household head (male or female), wealth index (poor, middle, and rich), educational status (no education, primary education, secondary education, and higher education), having a television (yes or no) and radio (yes or no) were individual-level predictor variables.

Community level variables: Community level education (lower/higher), the place of residence (urban/rural), community level media exposure (exposed/unexposed), region (Benishangul-Gumuz, Somali, Gambella, Afar, Oromia, SNNPR, Amhara, Tigray, and Harari) and City administration (Addis Ababa, and Dire Dawa).

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141 Data management and analysis

The first step in data handling was downloading the raw datasets from the DHS website. These contained pertinent demographic and socioeconomic factors as well as household-level data on sanitation facilities. Pretests comprising in-class instruction, biomarker training, and field exercises were conducted for ensuring the quality of the data. The field exercise was conducted in clusters, which were not included in the EDHS sample. A debriefing session was held with the pretest field staff, and adjustments to the questionnaires were done based on lessons drawn from the field practice.

Data cleaning techniques included re-coding, removing duplicates, and resolving missing values to get the data ready for analysis. The datasets underwent further processing after data cleaning in order to extract significant predictors and analytic findings. The management approach also ensured that sample weights from the DHS data were appropriately applied to all analyses, taking into account the complex survey design, to ensure nationally representative results. In order to prepare the spatial data, shapefiles of the Ethiopian regions were accessed, and sanitation data was superimposed on them.

Stata Version 17 was utilized to do regression analysis and descriptive statistics. Logistic
regression analysis was used to evaluate the relationships between outcome variables and predictor
variables because the outcome variables were dichotomous. Multivariable binary logistic
regression analysis was performed using bivariate analysis variables that had a p-value of less than
0.2. In the final model, statistical significance was determined by a p-value of less than 0.05 and a
95% confidence interval (CI) [35].

162 Multilevel Analysis

Model 1 included dependent and individual-level predictors, Model 2 included dependent and community-level predictors, Model 3 included all variables from Models 1 and 2, and Model 0 was a null model with no predictor variables. Random effects were measured using cluster variance (Vc), a proportional change in variance ((PCV ((Vc - Vn)/Vc))) the intraclass correlation coefficient (ICC(Vc/(Vc + 3.29)), and the median odds ratio (MOR (exp [(0.95) \sqrt{Vc}])) [36, 37]. The goodness-of-fit for all models was evaluated using AIC, BIC, and Deviance. Then the model with the lower value of deviance, AIC, and BIC, was demonstrating the best-fit model [38]. As

well as Multicollinearity, the effect of independent variables was measured using the varianceinflation factor (VIF).

172 Spatial and temporal analysis

173 Spatial Autocorrelation

174 In order to examine geographical variability, a geospatial study of the distribution of sanitary 175 facilities was carried out using ArcGIS version 17. The best essential instruments for access to 176 improved sanitation facilities within the designated term are both global and local indicators of 177 spatial correlation, which may be used to investigate the geographical distribution.

20 178 Global autocorrelations

Global autocorrelations analysis was performed in order to identify geographical variations in access to improved sanitation facilities. To determine whether the discrepancy is the result of non-random/dispersion or the clustering effect, global spatial autocorrelation (Moran's I index) was employed [39, 40]. Additionally, a basic exploratory spatial analysis was conducted to determine the country's geographic reliance distribution and the existence of better sanitary facilities. Places with similar access to sanitation tended to cluster together when Moran's I value was positive, while places with varying levels of sanitation were near one another when it was negative.

35 186 Local statistical analysis

Since global autocorrelations show a clustering effect (positive spatial autocorrelation) on the availability of sanitary facilities nationwide, more research utilizing figures and maps is required. In order to highlight the previously mentioned use of global autocorrelations (cluster effect) on access to sanitary facilities and to find patterns of geographical variation, hotspot analysis (Gettis-Ord Gi^{*}) was carried out. The spatial patterns of the dependent variables (access to sanitary facilities) were described using cluster and outlier analysis (Anselin local Moran is I). Since this cluster and outlier analysis allows for the identification of groups and regions where the discrepancies occur, it was utilized to confirm and accompany the display of extremes (the hotspot and cold spot) [41].

Additionally, Kriging interpolation techniques were employed to visualize and forecast sanitary
availability in locations that were not specifically studied. Kriging provided a continuous surface

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Ethiopia and generated more precise spatial projections by taking into

between survey points and the degree of spatial autocorrelation. This

regions that have experienced the greatest improvements in cleanliness

of sanitation access acros	ss Ethiopia and ge	nerated more precis	e spatial projection	n
account both the distance	e between survey	points and the deg	ree of spatial auto	c
allowed us to pinpoint the				
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over time as well as those	e with the lowest o	coverage.		
The authors used graphi	cal presentation to	o do temporal trend	d analysis in order	-
evolution of sanitation ac	cess through time	. The combination of	of trend and spatia	1
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for a thorough understan	aing of the region	hal neterogeneity an	id temporal evolut	10
access in Ethiopia betwee	en 2005 and 2019.			
Results				
Socio-demographic cha	racteristics of the	study population		
This study include 13,72	1 in 2005 EDHS.	16.702 in 2011 ED	HS. 16.650 in 201	(
2019 EDHS 8,663 partici				
had no education (63.59				
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Table 1. Socio-demograp	hic characteristics o	f study Part	ticipan	ts in Ethiopia	
Variables	EDHS 2005	EDHS	2011	EDHS 2016 (N=	EDH
		Q 7 1 6 - 0 -		1 5 5 7 0 1	0 1 1

Variables	EDHS 2005	EDHS 2011	EDHS 2016 (N=	EDHS 2019 (N=
	(N=13,721)	(N=16,702)	16,650)	8,663)
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Sex of HHH				
Male	10,243(74.65)	11,906(71.28)	11,413(68.55)	6,291(72.62)
Female	3,478(25.35)	4,796 (28.72)	5,237(31.45)	2,372(27.38)
Age of HHH				
<30	3,428(24.98)	4,823(28.88)	4,257(25.57)	2,520(29.09)
30-40	3,501(25.52)	4,116(24.64)	4,132(24.82)	2,287(26.40)
41-54	3,756(27.37)	4,047(24.23)	4,230(25.41)	1,717(19.82)
>54	3,036(22.13)	3,716(22.25)	4,031(24.21)	2,139(24.69)
Educational status of				
ННН				
No education	8,725(63.59)	9,309(55.74)	8,668(52.06)	4,128(47.65)
Primary	2,705(19.71)	5,020(30.06)	4,658(27.98)	2,715(31.34)
Second	1,754(12.78)	1,189(7.12)	1,686(10.12)	963(11.12)
Higher	495(3.61)	1,140(6.83)	1,580(9.49)	857(9.89)
Wealth index				
Poor	5,393(39.30)	6,506(38.95)	7,024(42.19)	3,498(40.38)

The authors used al presentation to do temporal trend analysis in order to examine the ess through time. The combination of trend and spatial studies allowed evolution of sanita for a thorough un ling of the regional heterogeneity and temporal evolution of sanitation n 2005 and 2019. access in Ethiopia

Results

Socio-demograph acteristics of the study population

This study include in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in 2019 EDHS 8,663 pants. The higher percentage of study participants in all EDHS data sets 55.74%, 52.06%, and 47.65%, respectively). According to Table 1, had no education ts in the 2005 EDHS, the 2011 EDHS, the 2016 EDHS, and the 2019 the majority of pa EDHS-88.30%, 76.98%, and 77.10%, respectively did not own a television (Table 1).

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Middle	2,055(14.98)	2,364(14.15)	2,057(12.35)	1,285(14.83)
Rich	6,273(45.72)	7,832(46.89)	7,569(45.46)	3,880(44.79)
Share toilet with other ho			1	
Yes	2,712(45.72)	4,467(46.12)	4,727(43.83)	2,222 (38.18
No	3,204(54.01)	5,204(53.73)	6,059(56.17)	3,598(61.82)
Having radio				
No	8,157(59.45)	9,658(57.83)	11,680(70.15)	6,170 (71.22
Yes	5,560(40.52)	7,040(42.15)	4,970(29.85)	2,493(28.78)
Having Television				
No	12,116(88.30)	13,643(81.68)	12,818(76.98)	6,679 (77.10
Yes	1,601(11.67)	3,051(18.27)	3,832(23.02)	1,984(22.90)
Community-level media exposure				
Unexposed	8,105(59.07)	8,973(53.72)	10,024(60.20)	5,195(59.97)
Exposed	5,616(40.93)	7,729(46.28)	6,626(39.80)	3,468(40.03)
Community-level educational status				
Lower	8,730(63.63)	9,309(55.74)	8,726(52.41)	4,308(49.73)
Higher	4,991(36.37)	7,393(44.26)	7,924(47.59)	4,355(50.27)
Residence				
Urban	3,666(26.72)	5,112(30.61)	5,232(31.42)	2,645(30.53)
Rural	10,055(73.28)	11,590(69.39)	11,418(68.58)	6,018(69.47)
Region				
Tigray	1,282(9.34)	1,730(10.36)	1,734(10.41)	714(8.24
Afar	806(5.87)	1,267(7.59)	1,220(7.33)	664 (7.66)
Amhara	2,066(15.06)	2,071(12.40)	1,902(11.42)	1,007(11.62)
Oromia	2,155(15.71)	2,165(12.96)	1,988(11.94)	1,018(11.75
Somali	796(5.80)	975(5.84)	1,564(9.39)	657(7.58)
Benishangul-Gumuz	869(6.33)	1,323(7.92)	1,280(7.69)	734(8.47)
SNNPR	1,933(14.09)	2,045(12.24)	1,897(11.39)	1,017(11.74)
Gambella	820(5.98)	1,215(7.27)	1,280(7.69)	693(8.00)
Harari	904(6.59)	1,201(7.19)	1,135(6.82)	719(8.30)
Addis Ababa	1,333(9.72)	1,524(9.12)	1,489(8.94)	702(8.10)
Dire Dawa	757(5.52)	1,186(7.10)	1,161(6.97)	738(8.52)
Key: EDHS= Ethiopian Nationalities Republic				

215 Trends of Sanitation facilities in Ethiopia

Figure 1 below presented that the trend of improved sanitation facilities in Ethiopia was 20.46%,
217 25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively (figure
218 1).

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1		
2 3 4	221	Factors Associated with Sanitation Facilities Accessibility
5 6	222	The odds of accessibility to improved sanitation facilities among participants with educational
7 8	223	status of primary, secondary, and higher were 2.43 (AOR = 2.43, 95% CI :(2.00, 2.95)), 2.02
9	224	(AOR = 2.02, 95% CI :(1.61, 2.54)), and 4.12 (AOR = 4.12, 95% CI :(3.35, 7.54) times more
10 11 12	225	likely respectively, compared to those with no education.
13	226	Study participants with wealth status of the middle, and rich were 1.49 (AOR = 1.49, 95% CI :(
14 15	227	1.21, 1.83)), and 3.15 (AOR = 3.15, 95% CI :(2.55, 3.89)) times more likely in the odds of
16 17	228	accessing improved sanitation facilities respectively, compared to those counterparts poor.
18 19	229	The odds of accessing improved sanitation facilities among study participants watched television
20 21	230	were 5.49 (AOR= 5.49, 95% CI: (4.37, 6.89)) more likely compared to counterparts who did no
22 23	231	watching television.
24 25	232	Community-level education was a statistically significant predictor variable. The odds of accessing
26 27	233	improved sanitation facilities among Communities with higher educational levels were 3.90
28 29	234	(AOR= 3.90, 95% CI: (3.15, 4.82) times more likely compared to the community with lower
30 31	235	education.
32 33	236	The chance of accessing improved sanitation facilities among communities exposed to media was
34 35	237	5.61 (AOR= 5.61, 95% CI: (3.84, 10.09)) times more likely than in the community unexposed to
36 37	238	the media.
38 39	239	The odds of accessibility-improved sanitation facilities among the study population living in urban
40	240	areas were 9.08 (AOR= 9.08, 95% CI: (6.69, 12.33) times more likely compared to the o study
41 42	241	population living in rural areas.
43 44	242	Communities across various regions, including Tigray (54% less likely, AOR=0.46; 95% CI: 0.37,
45 46	243	0.57), Afar (33% less likely, AOR=0.67; 95% CI: 0.51, 0.86), Somali (77% less likely, AOR=0.23;
47 48	244	95% CI: 0.18, 0.29), Amhara (60% less likely, AOR=0.40; 95% CI: 0.32, 0.49), Benishangul
49 50	245	Gumuz (37% less likely, AOR=0.63; 95% CI: 0.49, 0.80), Gambella (55% less likely, AOR=0.45;
51	246	95% CI: 0.35, 0.57), Harari (36% less likely, AOR=0.64; 95% CI: 0.52, 0.80), SNNRP (72% less
52 53 54 55 56	247	likely, AOR=0.28; 95% CI: 0.22, 0.34), and Dire Dawa (72% less likely, AOR=0.28; 95% CI:
57 58 59 60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

0.22, 0.35), exhibit decreased access to improved sanitation facilities compared to communities inAddis Ababa.

The median odds ratio (MOR), proportion change in variance (PCV), and intra-cluster correlation coefficient (ICC) were used to illustrate the random changes in cleanliness. According to the null model's ICC, variations through cluster regions accounted for 67.65% of the overall variability in access to improved sanitation services. According to Models 1 and 2, individual and community-level characteristics accounted for 59.74% and 26.35% of the Proportion Change in Variance (PCV) of the variation in the communities' access to better sanitation, respectively. If two areas were chosen at random, the MOR between the area with the greatest access to improved sanitary facilities and the region with the least access was 7.07.

Using the lowest AIC, DIC, and Deviance values, the model statistics showed a fair fit.
Consequently, the best-fit model was validated by the final model's lowest AIC; DIC, and
Deviance, which were 11,151.08, 11,282.33, and 11,117.0824, respectively (Table 2 and Table 3)

Table 2. Multilevel binary logistic regression analysis of predictors towards accessibility of
sanitation facilities in Ethiopia, EDHS 2011

Variables	Model 0	Model 1	Model 2	Model 3
	(Null	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
	model)			
Individual leve	l Factors			1
Sex of HHH				
Male		0.97(0.82,1.04)		1.01(0.84,1.11)
Female		1	1	1
Age of HHH	I	1		
<30		0.97(0.94,1.01)		0.96 (0.20,2.34)
30-40		0.57(0.35,2.02)		1.49(0.13,2.41)
41-54		0.43(0.22,0.61)		1.17(0.86,1.59)
>54		1	1	1
Educational stat	tus	·		
No education		1		1
Primary		3.23 (2.63,3.96)**		2.43(2.00,2.95)**
Secondary		6.36(5.26,7.67)**		2.02(1.61,2.54)**
Higher		8.11 (7.16,9.19)*		4.12(3.35,7.54)**
Wealth index				
Poor		1		1
Middle		2.96 (2.34,4.24)**		1.49 (1.21,1.83)**

	Rich	5.48 (3.45,5.89)**		3.15(2.55,3.89)**
	Having television			
	No	1		1
	Yes	4.81(4.16,5.56)**		5.49(4.37,6.89)**
	Community level fa	ctors		
	Community level edu	ication		
	Higher		6.50(5.82,7.27)**	3.90(3.15,4.82)**
	Lower		1	1
	Community-level me	dia exposure		
	Exposed		6.07(5.42,6.81)**	5.61(3.84,10.09)**
	Unexposed		1	1
	Type of residence			
	Urban		16.74(11.85, 23.65)**	9.08(6.69,12.33)**
	Rural		1	1
	Region			
	Tigray		0.50(0.41,0.62)**	0.46(0.37,0.57)**
	Afar		0.86(0.67,1.09)	0.67(0.51,0.86)*
	Amhara		0.43(0.35,0.53)**	0.40(0.32,0.49)**
	Oromia		0.89 (0.72,1.09)	0.90(0.73,1.12)
	SNNRP		0.25(0.20,0.31)*	0.28(0.22,0.34)**
	Somali		0.33(0.26,0.41)**	0.23(0.18,0.29)**
	Benishangul		0.74(0.59,0.94)*	0.63(0.49,0.80)**
	Gumuz		4.	
	Gambella		0.51(0.41,0.64)**	0.45(0.35,0.57)**
	Harari			0.64(0.52.0.80)**
	Addis Ababa		1	1
	Dire Dawa		0.25(0.21,0.31)**	0.28(0.22,0.35)**
	VIF	2.35	2.27	2.05
	1 = reference, **P-	value < 0.001(Adjusted OI	R), *P-value < 0.05 (Adjus	ted OR), AIC=Akaik
	information criteria	, BIC=Bayesian informatio	n criteria. HHH =househo	ld head. HH=househo
				-
	Model 0 (Null mod	el) was fitted without predi	ctor variables. ; Model 1 1	s adjusted for individu
	level variables. Mo	odel 2 is adjusted for comm	nunity-level variables; Mo	del 3 is the final mod
	adjusted for both in	dividual- and community-le	vel predictors	
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less improved sanitation accessibility. As illustrated in the figur areas of the country (Addis Ababa and Dire Dawa) with greate facilities, while the green color (the majority of the country) in		
	ares below, the ser access to im	red color denotes proved sanitation

267	Table 3: Measures variation metrics and the model fitness test statistics used for included models

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Discussion

Using multilevel and geographical analysis techniques on Ethiopia's 2005-2019 EDHS datasets, the studies are unique in their thorough investigation of geographic variances and temporal changes in sanitation facilities. Their thorough investigation into the ways in which access to sanitation infrastructure has changed over time and differed among Ethiopia's many regions has produced a fresh contribution by illuminating hitherto unseen trends and inequalities. In order to reduce inequities and enhance overall sanitation access in Ethiopia, this research highlights locations for focused interventions and offers insightful information about the dynamic nature of sanitation service.

To hygienically isolate human excreta from human touch, which causes many infectious diseases, improved sanitation facilities must be accessible in a sustainable and fair manner [42]. This study's primary goal was to examine, using four consecutive EDHS datasets, the spatiotemporal variation and factors linked to improved sanitation facilities that are accessible in Ethiopia. According to these findings, the percentage of households with access to improved sanitation facilities was 20.46% in EDHS 2005, 25.61% in EDHS 2011, 25.86% in EDHS 2016, and 27.45% in EDHS 2019. The rise from 2011 to 2016 was only 0.25%, but the increase from 2005 to 2011 was 5.15%. These results indicate that, between 2005 and 2019, Ethiopia's access to better sanitation facilities improved at relatively modest steady rates. This outcome is consistent with other research showing that certain nations have made significant strides toward SDG 6, while others look to be stuck at low levels of sanitation coverage with little or no development [43]. Such setback with little or no development levels of access to improved sanitation facilities is the experience of developing countries including Ethiopia [44]. The construction of sanitation facilities may receive less attention from the government and non-governmental organizations because of international environmental change, poverty, and the nation's instability brought on by the trauma of the civil war. This result is in line with previously conducted research conducted global [33, 45-49].

Based on four EDHS datasets, the geographical analysis's results for Global Moran's autocorrelation, hotspot, cluster, and Kriging revealed significant differences in Ethiopia's access to better sanitation services. Among other regions of the nation, Addis Ababa and Dire Dawa were identified as high hot spots for improved sanitation facilities based on the findings of the Kriging analysis and hot spot analysis conducted in all EDHS. This result demonstrated that access to better sanitation facilities varies significantly by region across the nation. It ran counter to aim 6.2 of the

2030 Sustainable Development Goals, which is to "end open defecation and provide access to adequate and equitable sanitation for all"[50]. This variation could be the difference in economic growth, overpopulation growth, unplanned urbanization, and inaccessibility of infrastructure, government overload towards other burning daily tasks, socio-political instability, awareness, and adaptability towards sanitation facilities.

The household head's educational level, television ownership, and wealth index were individual-level predictors linked to access to better sanitation facilities, while community-level predictor variables included education, media exposure, residence type, and region.

Household heads with higher levels of education were more likely to have access to better sanitary facilities than heads with lower levels of education. Ethiopia, Kenva, West and Central Africa, Bangladesh, Benin, and Vietnam have all conducted research that corroborate this conclusion [51-54]. The community with higher education accessed improved sanitation facilities than part of the community with lower education. This finding was in line with other previous studies conducted in different parts of the world [23, 55, 56]. Other possible explanation for this discrepancy is that more people that are educated may be aware of the link between better sanitary facilities and health. If so, compared to household heads with lower educational background, they are excited to have these sanitation services.

Access to better sanitary facilities was correlated with wealth status in a proportionate manner. Compared to the poorest homes, wealthy and middle-class households were more likely to have access to better sanitary facilities. The research conducted in Ghana, Benin, Vietnam, and Eswatini supports this conclusion [52, 57-59]. This discrepancy may result from the development of better sanitation facilities like septic tanks and pour-flush toilets; the impoverished may find it difficult to afford slab pit latrines and composting toilets.

When all other factors were held constant, families with television had a higher chance of having access to better sanitary facilities than those without. This may be because residents spent a lot of time watching television, which serves as a visual information source about topics like how better cleanliness can prevent the spread of disease. The other statistically significant predictor of access to better sanitation facilities at the community level was media exposure. In Ethiopia, householders who were exposed to community-level media-whether it was radio, television, or both-were

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more likely to have access to better sanitation. This result was consistent with earlier research carried out in Ethiopia [22, 23], and sub-Saharan Africa [60].

Compared to households in rural areas, urban households are more likely to have access to better sanitation services. A prior Ethiopian study that showed Ethiopia's rural communities are severely trailing behind in the battle to achieve SDGs supported this issue 6.2 [43] and the other study done in Vietnam [57]. Different amounts of improved sanitation facilities were available to households located in different parts of Ethiopia. Addis Ababa, the capital, was better to the other parts of the country. This finding is aligns with the studies done in Kenva [61]. Nepal [62] and WHO. UNICEF, 2019 report [63] which indicated that persist disparities in access to WASH services in rural versus urban settings. This discrepancy could be explained by the fact that Addis Ababa serves as both the nation's capital and the headquarters of the Africa Union, providing access to better infrastructure, including sanitary facilities. Low socioeconomic position, regional sociopolitical instability, ignorance, and a lack of ability to adjust to sanitary facilities could all be contributing factors[64].

The self-report nature of data collection, which leads to interviewer bias, social acceptability bias, recall bias and incompleteness of the recent mini demographic health survey (EDHS 2019), could be potential sources of errors and the limitations of this study.

Conclusion

According to the study's general findings, Ethiopia's access to sanitary facilities has gradually increased over time. Additionally, there was geographical variation in the country's accessibility of improved sanitation facilities that was statistically significant. To achieve the suggested goal, the rate of advancement in universal access to sanitary facilities (SDG 6.2) in 2030 should be accelerated. The following parameters were statistically linked to the accessibility of sanitation facilities in Ethiopia: region, type of habitation, wealth index, community-level education, community-level media exposure, educational status, and television viewing. This study recommended that local and international organizations focus on solutions that allow for the advancement of universal access to sanitary facilities, particularly in developing nations.

2		
3 4	376	Strengths and Limitations of this study
5 6	377	The first strength is the use of multi-EDHS data, which allows trend analysis of Ethiopia's
7 8	378	sanitation situation.
9 10	379	The second strength is that a large, nationally representative sample is ensured by using data from
11 12	380	numerous Demographic and Health Surveys, increasing the generalizability of findings throughout
13 14	381	Ethiopia.
15 16	382	The third strength, DHS surveys provide detailed information on the types of sanitation facilities,
17 18	383	from basic to improved, which allows for a significance understanding of the sanitation
19 20	384	countryside in Ethiopia.
21 22	385	The first limitation, there could be social desirable bias since the data were collected through face-
23 24	386	to-face interview.
25 26	387	The second limitation, while the quantitative analysis identifies trends and spatial disparities, it
27 28	388	may not provide insights into the behavioral, and cultural level factors influencing sanitation
28 29 30	389	adoption and usage.
31 32	390	Abbreviations
33 34	391	AIC: Akaike's Information Criterion, AOR: Adjusted Odds Ratio, CI: Confidence Interval, DHS:
35 36	392	Demographic and Health Survey, EAs: Enumeration Areas, EDHS: Ethiopian Demographic and
37	393	Health Survey, ICC: Intra Class Correlation, MOR: Median Odd Ratio, PCV: Proportional Change
38 39 40	394	in Variance
41 42	395	Declarations
43	396	Ethics approval and consent to participate
44 45	397	This study was based on secondary data from the Ethiopian Demographic and Health Survey and
46 47	398	secured the permission letter from the main Demographic Health and Survey. Permission for data
48 49	399	access was obtained from a major Demographic and Health Survey through an online request at
50	400	(https://www.dhsprogram.com/data/dataset_admin/login_main.cfm.). Participant consent was not
51 52	401	directly obtained since authors used secondary data.
53 54	402	Patient and Public Involvement
55	403	Not applicable.
56 57		
58 59		
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

1 2					
3 4	404	Consent for publication			
5 6	405	Not applicable.			
7 8	406	Availability of data and materials			
9 10	407	This research was done using a publicly available dataset found at			
11 12	408	https://www.dhsprogram.com/data/dataset_admin/login_main.cfm after approval from Data			
13 14 15 16 17 18 19	409	Archivist of the Demographic and Health Surveys (DHS) Program.			
	410	Competing interests			
	411	There is no any competing interest.			
20 21	412	Funding			
22 23	413	The authors have not received any specific grant for this research from public, commercial, or not-			
24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44	414	for-profit funding agencies			
	415	Authors' contributions			
	416	JA Engaged in data curation. JA Conducted the statistical analysis. JA, MT, and WM involved in			
	417	investigation of the study. JA and WM had full access to all the data in the study and take			
	418	responsibility for the integrity of the data and the accuracy of the data analysis. JA, MT, and WM			
	419	done validation and visualization. JA and WM conducted the write-up and drafted the manuscript.			
	420	All authors involved in review & editing. JA is responsible for the overall content as guarantors.			
	421	Acknowledgments			
	422	The author acknowledges the Ethiopian Central Statistical Agency for providing them with the			
	423	data and shape files for this study.			
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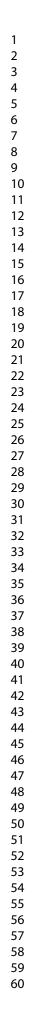
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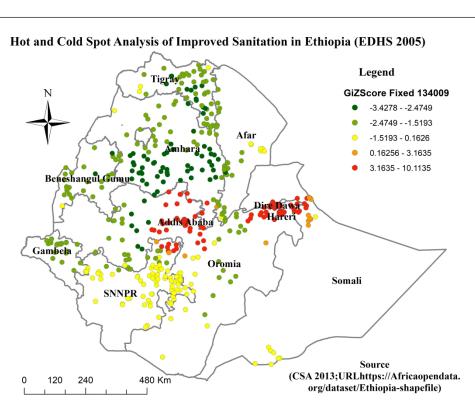
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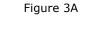
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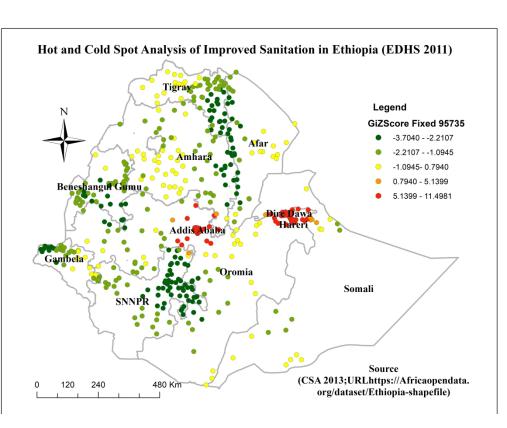
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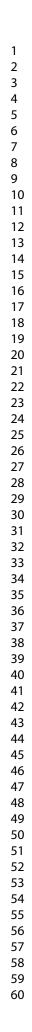


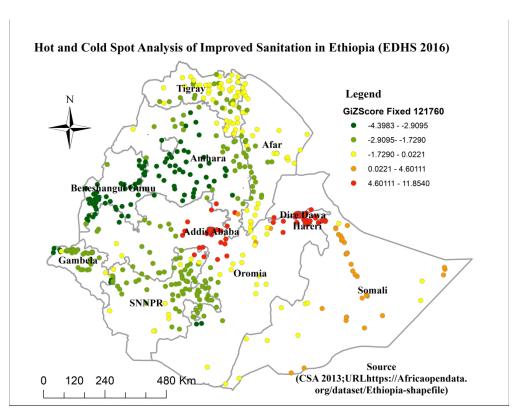


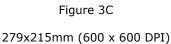
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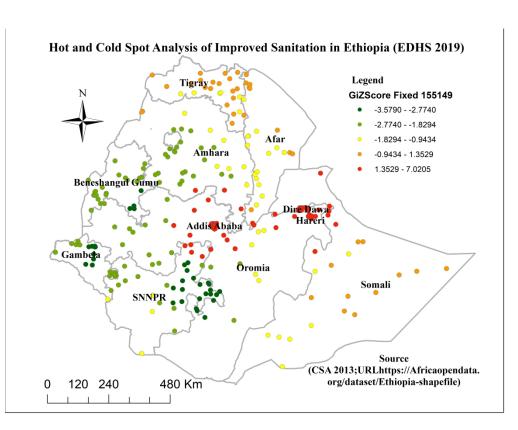
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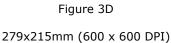
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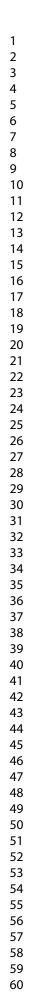


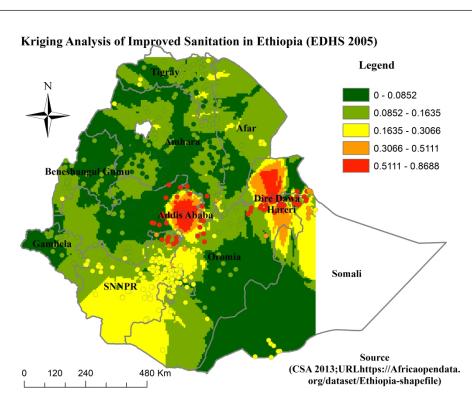


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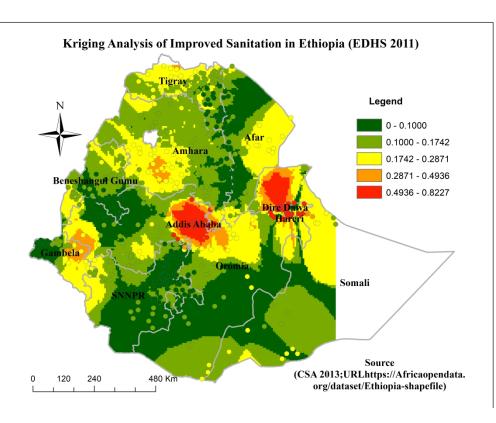
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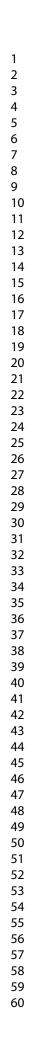






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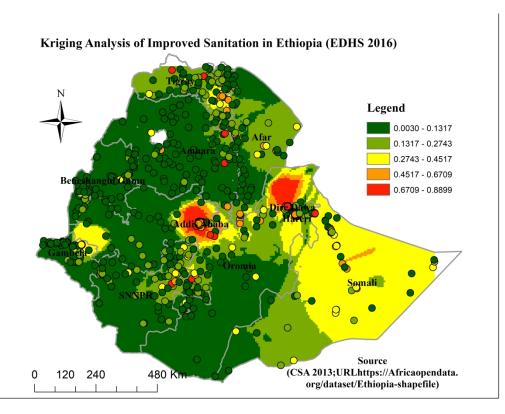


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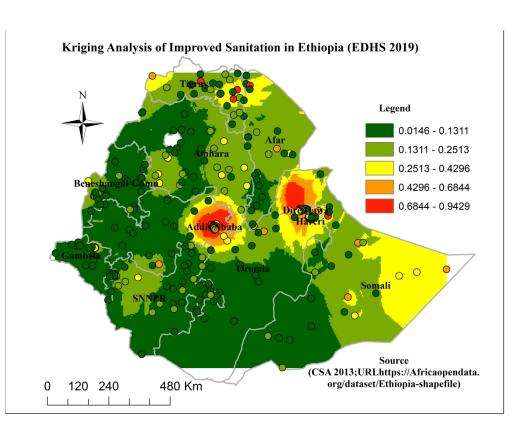


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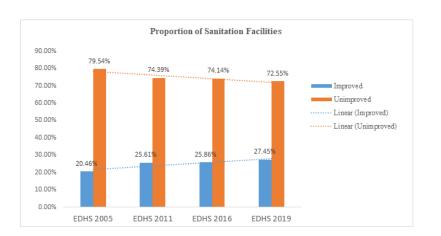
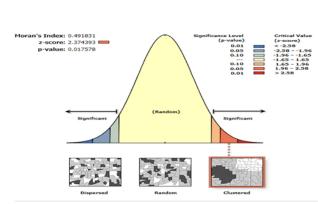


Figure 1

216x121mm (96 x 96 DPI)



Given the z-score of 2.37439300313, there is a less than 5% likelihood that this clustered pattern could be the result of random chance.

Figure 2A

216x121mm (96 x 96 DPI)

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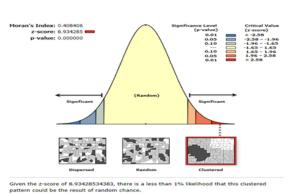
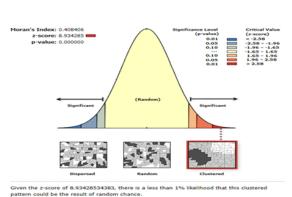


Figure 2B

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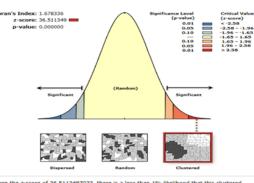
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Figure 2C

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Given the z-score of 36.5113487033, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Figure 2D

216x121mm (96 x 96 DPI)

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Temporal trends and spatial heterogeneity of sanitation facilities in Ethiopia: evidence from the 2005-2019 Demographic and Health Surveys

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Abstract **Background:** The main aim of sanitation is to prevent human contact with fecal pathogens to decrease occurrences of diseases. However, no region in the world is on the right track to accomplish Sustainable development goal (SDG) 6.2 for universal access to sanitation. Sub-Sahara Africa, Ethiopia included, is significantly behind in meeting the 2030 SDG 6.2 targets. Hence, this study focused on the spatial and temporal analysis of sanitation in Ethiopia based on four demographic health surveys. **Design:** This research was undertaken among households in Ethiopia based on a weighted sample size. Variables with a p-value below 0.2 in bivariable analysis were incorporated into the multivariable analysis. Subsequently, a 95% CI and a p-value < 0.05 were utilized to assess the statistical significance of the final model. Global and local indicators of spatial correlation were done. Statistical analyses were performed using STATA 17, and ArcGIS 10.7 software. **Results:** This study includes 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in 2019 EDHS 8,663 households. The prevalence of improved sanitation facilities in Ethiopia was 20.46%, 25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively. Global Moran's I spatial autocorrelations, hotspots, and spatial interpolation analysis indicated the inequality of improved sanitation facilities. Educational status of primary (AOR = 2.43, 95% CI : 2.00, 2.95), secondary (AOR = 2.02, 95% CI : 1.61, 2.54), and higher (AOR = 4.12, 95% CI :3.35, 7.54), watching television (AOR= 5.49, 95% CI: 4.37, 6.89), urban areas (AOR=

9.08, 95% CI: 6.69, 12.33), and region were factors statistically associated with sanitation
facilities.

47 Conclusion: The overall finding of this study concludes a very slow increment in sanitation
48 facilities over time and presence of geographical heterogeneity in Ethiopia. Educational status,
49 watching television, wealth index, community-level education, type of residence, and region were
50 factors statistically associated with sanitation facilities.

51 Keywords: EDHS, Ethiopia, Improved Sanitation, Spatiotemporal variation

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54 STRENGTHS AND LIMITATIONS OF THIS STUDY

 The first strength is using multi EDHS data, which enable to show trend analysis of sanitation status in Ethiopia.

 The second strength is using data from multiple Demographic and Health Surveys ensures a large, nationally representative sample, which increases the generalizability of findings across Ethiopia.

- ✓ The third strength, DHS surveys provide detailed information on the types of sanitation
 facilities, from basic to improved, which allows for a significance understanding of the
 sanitation countryside in Ethiopia.
- ✓ The first limitation, there could be social desirable bias since the data were collected through
 face-to-face interview.
- The second limitation, while the quantitative analysis identifies trends and spatial disparities,
 it may not provide insights into the behavioral, and cultural level factors influencing sanitation
 adoption and usage.

68 Background

Sanitation refers to the endowment of services and facilities for the safe and clean controlling of
human excreta, from the toilet to handling and containment to the final end-use or removal [1].
Sanitation is an integral component of basic human rights comparable to food, shelter, and water
and is vital for healthy life [2].

According to the United Nations (UN-2018) report, in the world, around 4.5 billion people had no safe sanitation sand 892 million continue to practice Open Defecation (OD) [3, 4]. Inadequate access to sanitation is a principal reason for poverty in unindustrialized nations because it causes early mortality [5, 6]. The World Health Organization (WHO) estimated in 2019 that over 800,000 people die each year from diarrhea brought on by inadequate water, sanitation, and hygiene (WASH), and that two billion people's drinking water sources were tainted with excrement. Climate change, shifting precipitation patterns, increasing urbanization, and a dearth of practical, context-specific guidance on adaption strategies for sanitation service providers are all predicted to have an influence on the sanitation sector globally [7-9]. Over 70% of the population in Eastern and Southern Africa—340 million people—do not have access to basic sanitation services, while

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19% defecate in the open, 179 million use unimproved facilities, and 63 million utilize shared sanitation facilities [10].

The Sustainable Development Goals (SDGs 6.2) aim to guarantee universal access to fair sanitation by 2030 as a result of these issues [11]. SDG 6.2 of the United Nations, which emanated in 2015 from the Millennium Development Goals, aims at equitable access to safe and affordable sanitation for all by 2030 (10). The main aim of this SDG is to prevent human contact with fecal pathogens to decrease occurrences of diseases [12, 13]. However, urban sewer connections are growing at an embarrassingly slow rate of 0.14% per year, and no place in the world is on track to achieve SDG 6.2 for universal access to sanitation [14]. Sub-Saharan African (SSA) nations, in particular, are well behind schedule in achieving SDG 6.2 of the 2030 agenda because of their fast population expansion and inadequate investment in sanitary infrastructure [15, 16]. At the same time, disparities in sub-Saharan African nations' access to sanitary facilities were more noticeable [17]. There are differences between nations, primarily in terms of urban and rural housing, which showed that people in rural areas had far worse access to sanitation than people in urban areas [18]. Low and middle-income nations exhibit this subnational variance in access to improved sanitation facilities, which is defined as the range of values from the unit with the highest level of access to the unit with the lowest level of access or no access at all [19]. Like other developing countries [20] access to sanitation is a challenge across Ethiopia [21], as well as there are disparities among the regions of the country. However, countries have the power to either advance or impede the development of fair access to better sanitary facilities.

Previous studies in Ethiopia were based on a single EDHS or only multilevel analysis or spatial analysis in order to investigate improved sanitation facilities [22]. These researches are unable to demonstrate the trend of better sanitary facilities over time. As in earlier research, the enhanced sanitation source is linked to residence, educational achievement, television viewing, household size, region, and wealth index [23-25]. In order to better understand the progress and geographic variance within Ethiopia, this study concentrated on the spatial and temporal analysis of sanitation facilities based on a combination of different demographic health surveys conducted in 2005, 2010, 2016, and 2019.

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113 Methods

114 Study area and Data source

The study was carried out in Ethiopia, which consists of two administrative cities (Addis Ababa and Dire-Dawa) and nine geographical regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples Region (SNNPR), Gambella, and Harari). The nation is situated in the Horn of Africa, with coordinates of 40.4897° East longitude and 9.145° North latitude [26]. The four consecutive Ethiopian Demographic and Health Surveys (EDHS 2005, 2011, 2016, and 2019) database survey were used in this investigation. These are therefore population-based surveys that are nationally representative and have sizable sample sizes at various points in time.

123 The DHS website, <u>https://www.dhsprogram.com/data/dataset_admin/login_main.cfm</u>, provides
 124 access to open source EDHS data.

All EDHS samples were a two-stage stratified cluster sample [27], sampling weights were calculated based on sampling probabilities separately for each sampling stage and each cluster. In 2005 surveys, 540 enumeration areas (EAs) (139 urban and 401 rural areas) [28], 2011 EDHS, 624 EAs (187 urban and 437 rural areas) [29], 2016 EDHS 645 EAs (202 in urban areas and 443 in rural areas) [30], and 2019 EDHS 305 EAs (93 in urban areas and 212 in rural areas) [31]were selected using systematic sampling with likelihood proportional to size.

In the second stage of selection, a fixed number of 30 households per cluster were selected with an equal probability of systematic selection from the newly created household listing. The field practice was conducted in Adama in clusters that were not part of the survey sample. Ethiopian public health institute investigators, an ICF technical specialist, an advisor, and representatives from other organizations, including central statistics agency, the Federal Ministry of Health, the World Bank, and USAID, supported the data collection in this EDHS data collection [28].

Among included households, 13,721, 16,702, 16, 650, and 8,663 were successfully interviewed in EDHS 2005, 2011, 2016, and 2019, respectively [28, 30]. Weighted by sampling weight was done to do a reliable statistical analysis. The geographical location data were taken from selected respective Enumeration Areas (EAs).

141 Study Variables

Outcome variables

The dependent variable was the sanitation facilities. The sanitation type designated as '1' represents 'improved sanitation', which can be accessed through flush/pour flush to piped sewer systems, septic tanks, or pit latrines; ventilated improved pit latrines, composting toilets, or pit latrines with slabs; and '0' represents 'unimproved sanitation' since it includes pit latrines without a platform or slab, hanging latrines or bucket latrines, and open defecation [32-34].

Predictor variables

Individual level variables: sex of household head (male or female), wealth index (poor, middle,
and rich), educational status (no education, primary education, secondary education, and higher
education), having a television (yes or no) and radio (yes or no) were individual-level predictor
variables.

153 Community level variables: Community level education (lower/higher), the place of residence
 154 (urban/rural), community level media exposure (exposed/unexposed), region (Benishangul 155 Gumuz, Somali, Gambella, Afar, Oromia, SNNPR, Amhara, Tigray, and Harari) and City
 156 administration (Addis Ababa, and Dire Dawa).

5 157 Data management and analysis

The first step in data handling was downloading the raw datasets from the DHS website. These contained pertinent demographic and socioeconomic factors as well as household-level data on sanitation facilities. Pretests comprising in-class instruction, biomarker training, and field exercises were conducted for ensuring the quality of the data. The field exercise was conducted in clusters, which were not included in the EDHS sample. A debriefing session was held with the pretest field staff, and adjustments to the questionnaires were done based on lessons drawn from the field practice.

Data cleaning techniques included re-coding, removing duplicates, and resolving missing values to get the data ready for analysis. The datasets underwent further processing after data cleaning in order to extract significant predictors and analytic findings. The management approach also ensured that sample weights from the DHS data were appropriately applied to all analyses, taking

into account the complex survey design, to ensure nationally representative results. In order to
prepare the spatial data, shapefiles of the Ethiopian regions were accessed, and sanitation data was
superimposed on them.

Stata Version 17 was utilized to do regression analysis and descriptive statistics. Logistic regression analysis was used to evaluate the relationships between outcome variables and predictor variables because the outcome variables were dichotomous. Multivariable binary logistic regression analysis was performed using bivariate analysis variables that had a p-value of less than 0.2. In the final model, statistical significance was determined by a p-value of less than 0.05 and a 95% confidence interval (CI) [35].

178 Multilevel Analysis

Model 1 included dependent and individual-level predictors, Model 2 included dependent and community-level predictors, Model 3 included all variables from Models 1 and 2, and Model 0 was a null model with no predictor variables. Random effects were measured using cluster variance (Vc), a proportional change in variance ((PCV ((Vc - Vn)/Vc)) the intraclass correlation coefficient (ICC(Vc/(Vc + 3.29)), and the median odds ratio (MOR (exp [(0.95) \sqrt{Vc}])) [36, 37]. The goodness-of-fit for all models was evaluated using AIC, BIC, and Deviance. Then the model with the lower value of deviance, AIC, and BIC, was demonstrating the best-fit model [38]. As well as Multicollinearity, the effect of independent variables was measured using the variance inflation factor (VIF).

39 188 Spatial and temporal analysis

189 Spatial Autocorrelation

In order to examine geographical variability, a geospatial study of the distribution of sanitary facilities was carried out using ArcGIS version 17. The best essential instruments for access to improved sanitation facilities within the designated term are both global and local indicators of spatial correlation, which may be used to investigate the geographical distribution.

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197 Global autocorrelations

Global autocorrelations analysis was performed in order to identify geographical variations in access to improved sanitation facilities. To determine whether the discrepancy is the result of nonrandom/dispersion or the clustering effect, global spatial autocorrelation (Moran's I index) was employed [39, 40]. Additionally, a basic exploratory spatial analysis was conducted to determine the country's geographic reliance distribution and the existence of better sanitary facilities. Places with similar access to sanitation tended to cluster together when Moran's I value was positive, while places with varying levels of sanitation were near one another when it was negative.

19 205 Local statistical analysis

Since global autocorrelations show a clustering effect (positive spatial autocorrelation) on the availability of sanitary facilities nationwide, more research utilizing figures and maps is required. In order to highlight the previously mentioned use of global autocorrelations (cluster effect) on access to sanitary facilities and to find patterns of geographical variation, hotspot analysis (Gettis-Ord Gi^{*}) was carried out. The spatial patterns of the dependent variables (access to sanitary facilities) were described using cluster and outlier analysis (Anselin local Moran is I). Since this cluster and outlier analysis allows for the identification of groups and regions where the discrepancies occur, it was utilized to confirm and accompany the display of extremes (the hotspot and cold spot) [41].

Additionally, Kriging interpolation techniques were employed to visualize and forecast sanitary availability in locations that were not specifically studied. Kriging provided a continuous surface of sanitation access across Ethiopia and generated more precise spatial projections by taking into account both the distance between survey points and the degree of spatial autocorrelation. This allowed us to pinpoint the regions that have experienced the greatest improvements in cleanliness over time as well as those with the lowest coverage.

The authors used graphical presentation to do temporal trend analysis in order to examine the
 evolution of sanitation access through time. The combination of trend and spatial studies allowed
 for a thorough understanding of the regional heterogeneity and temporal evolution of sanitation
 access in Ethiopia between 2005 and 2019.

- 56 225

Results

227 Socio-demographic characteristics of the study population

This study include 13,721 in 2005 EDHS, 16,702 in 2011 EDHS, 16,650 in 2016 EDHS, and in 2019 EDHS 8,663 participants. The higher percentage of study participants in all EDHS data sets had no education (63.59%, 55.74%, 52.06%, and 47.65%, respectively). According to Table 1, the majority of participants in the 2005 EDHS, the 2011 EDHS, the 2016 EDHS, and the 2019 EDHS—88.30%, 81.68%, 76.98%, and 77.10%, respectively did not own a television (Table 1).

Table 1. Socio-demographic characteristics of study Participants in Ethiopia

Variables	EDHS 2005	EDHS 2011	EDHS 2016 (N=	EDHS 2019 (N=
	(N=13,721)	(N=16,702)	16,650)	8,663)
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Sex of HHH				
Male	10,243(74.65)	11,906(71.28)	11,413(68.55)	6,291(72.62)
Female	3,478(25.35)	4,796 (28.72)	5,237(31.45)	2,372(27.38)
Age of HHH				
<30	3,428(24.98)	4,823(28.88)	4,257(25.57)	2,520(29.09)
30-40	3,501(25.52)	4,116(24.64)	4,132(24.82)	2,287(26.40)
41-54	3,756(27.37)	4,047(24.23)	4,230(25.41)	1,717(19.82)
>54	3,036(22.13)	3,716(22.25)	4,031(24.21)	2,139(24.69)
Educational status of HHH		Q,		
No education	8,725(63.59)	9,309(55.74)	8,668(52.06)	4,128(47.65)
Primary	2,705(19.71)	5,020(30.06)	4,658(27.98)	2,715(31.34)
Second	1,754(12.78)	1,189(7.12)	1,686(10.12)	963(11.12)
Higher	495(3.61)	1,140(6.83)	1,580(9.49)	857(9.89)
Wealth index				
Poor	5,393(39.30)	6,506(38.95)	7,024(42.19)	3,498(40.38)
Middle	2,055(14.98)	2,364(14.15)	2,057(12.35)	1,285(14.83)
Rich	6,273(45.72)	7,832(46.89)	7,569(45.46)	3,880(44.79)
Share toilet with other ho	useholds			
Yes	2,712(45.72)	4,467(46.12)	4,727(43.83)	2,222 (38.18)
No	3,204(54.01)	5,204(53.73)	6,059(56.17)	3,598(61.82)
Having radio				
No	8,157(59.45)	9,658(57.83)	11,680(70.15)	6,170 (71.22)
Yes	5,560(40.52)	7,040(42.15)	4,970(29.85)	2,493(28.78)
Having Television				
No	12,116(88.30)	13,643(81.68)	12,818(76.98)	6,679 (77.10)
Yes	1,601(11.67)	3,051(18.27)	3,832(23.02)	1,984(22.90)
Community-level media exposure				
Unexposed	8,105(59.07)	8,973(53.72)	10,024(60.20)	5,195(59.97)

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$\begin{array}{c}1\\2\\3\\4\\5\\6\\7\\8\\9\\10\\11\\12\\13\\14\\15\\16\\17\\18\\19\\20\\21\\22\\23\\24\\25\\26\\27\\28\\29\\30\\31\\32\\33\\45\\36\\37\\38\\39\\40\\41\\42\\43\\44\end{array}$	11 of 37 234 235 236 237 238 239 240 241 242	Exposed Community-level educational status Lower Higher Residence Urban Rural Region Tigray Afar Amhara Oromia Somali Benishangul-Gurr SNNPR Gambella Harari Addis Ababa Dire Dawa Key: EDHS= Etl Nationalities Repu Trends of Sanita Figure 1 below pr 25.61%, 25.86%, 1). Factors Associat The odds of accesstatus of primary (AOR = 2.02, 95%
45 46	243	likely respectively
47		
48 49	244	Study participants
50	245	1.21, 1.83)), and
51	246	accessing improv

Exposed	5,616(40.93)	7,729(46.28)	6,626(39.80)	3,468(40.03)
Community-level				
educational status				
Lower	8,730(63.63)	9,309(55.74)	8,726(52.41)	4,308(49.73)
Higher	4,991(36.37)	7,393(44.26)	7,924(47.59)	4,355(50.27)
Residence				
Urban	3,666(26.72)	5,112(30.61)	5,232(31.42)	2,645(30.53)
Rural	10,055(73.28)	11,590(69.39)	11,418(68.58)	6,018(69.47)
Region				
Tigray	1,282(9.34)	1,730(10.36)	1,734(10.41)	714(8.24
Afar	806(5.87)	1,267(7.59)	1,220(7.33)	664 (7.66)
Amhara	2,066(15.06)	2,071(12.40)	1,902(11.42)	1,007(11.62)
Oromia	2,155(15.71)	2,165(12.96)	1,988(11.94)	1,018(11.75)
Somali	796(5.80)	975(5.84)	1,564(9.39)	657(7.58)
Benishangul-Gumuz	869(6.33)	1,323(7.92)	1,280(7.69)	734(8.47)
SNNPR	1,933(14.09)	2,045(12.24)	1,897(11.39)	1,017(11.74)
Gambella	820(5.98)	1,215(7.27)	1,280(7.69)	693(8.00)
Harari	904(6.59)	1,201(7.19)	1,135(6.82)	719(8.30)
Addis Ababa	1,333(9.72)	1,524(9.12)	1,489(8.94)	702(8.10)
Dire Dawa	757(5.52)	1,186(7.10)	1,161(6.97)	738(8.52)
Key: EDHS= Ethiopia Nationalities Republic	n demographic healt	th survey, HHH=Ho	ousehold head, SN	NPR= South nation

235 Trends of Sanitation facilities in Ethiopia

Figure 1 below presented that the trend of improved sanitation facilities in Ethiopia was 20.46%,
25.61%, 25.86%, and 27.45% based on EDHS 2005, 2011, 2016, and 2019, respectively (figure
1).

239 Factors Associated with Sanitation Facilities Accessibility

The odds of accessibility to improved sanitation facilities among participants with educational status of primary, secondary, and higher were 2.43 (AOR = 2.43, 95% CI :(2.00, 2.95)), 2.02 (AOR = 2.02, 95% CI :(1.61, 2.54)), and 4.12 (AOR = 4.12, 95% CI :(3.35, 7.54) times more likely respectively, compared to those with no education.

48 244 Study participants with wealth status of the middle, and rich were 1.49 (AOR = 1.49, 95% CI : (49 $_{50}$ 245 1.21, 1.83)), and 3.15 (AOR = 3.15, 95% CI : (2.55, 3.89)) times more likely in the odds of 51 $_{52}$ 246 accessing improved sanitation facilities respectively, compared to those counterparts poor.

59 60

The odds of accessing improved sanitation facilities among study participants watched television were 5.49 (AOR= 5.49, 95% CI: (4.37, 6.89)) more likely compared to counterparts who did no watching television.

Community-level education was a statistically significant predictor variable. The odds of accessing improved sanitation facilities among Communities with higher educational levels were 3.90 (AOR= 3.90, 95% CI: (3.15, 4.82) times more likely compared to the community with lower education.

The chance of accessing improved sanitation facilities among communities exposed to media was 5.61 (AOR= 5.61, 95% CI: (3.84, 10.09)) times more likely than in the community unexposed to the media.

The odds of accessibility-improved sanitation facilities among the study population living in urban
 areas were 9.08 (AOR= 9.08, 95% CI: (6.69, 12.33) times more likely compared to the o study
 population living in rural areas.

Communities across various regions, including Tigray (54% less likely, AOR=0.46; 95% CI: 0.37, 0.57), Afar (33% less likely, AOR=0.67; 95% CI: 0.51, 0.86), Somali (77% less likely, AOR=0.23; 95% CI: 0.18, 0.29), Amhara (60% less likely, AOR=0.40; 95% CI: 0.32, 0.49), Benishangul Gumuz (37% less likely, AOR=0.63; 95% CI: 0.49, 0.80), Gambella (55% less likely, AOR=0.45; 95% CI: 0.35, 0.57), Harari (36% less likely, AOR=0.64; 95% CI: 0.52, 0.80), SNNRP (72% less likely, AOR=0.28; 95% CI: 0.22, 0.34), and Dire Dawa (72% less likely, AOR=0.28; 95% CI: 0.22, 0.35), exhibit decreased access to improved sanitation facilities compared to communities in Addis Ababa.

The median odds ratio (MOR), proportion change in variance (PCV), and intra-cluster correlation coefficient (ICC) were used to illustrate the random changes in cleanliness. According to the null model's ICC, variations through cluster regions accounted for 67.65% of the overall variability in access to improved sanitation services. According to Models 1 and 2, individual and community-level characteristics accounted for 59.74% and 26.35% of the Proportion Change in Variance (PCV) of the variation in the communities' access to better sanitation, respectively. If two areas were chosen at random, the MOR between the area with the greatest access to improved sanitary facilities and the region with the least access was 7.07.

Using the lowest AIC, DIC, and Deviance values, the model statistics showed a fair fit.
Consequently, the best-fit model was validated by the final model's lowest AIC; DIC, and
Deviance, which were 11,151.08, 11,282.33, and 11,117.0824, respectively (Table 2 and Table 3)

Table 2. Multilevel binary logistic regression analysis of predictors towards accessibility ofsanitation facilities in Ethiopia, EDHS 2011

Variables	Model 0 (Null model)	Model 1 AOR (95% CI)	Model 2 AOR (95% CI)	Model 3 AOR (95% CI)
Individual leve	el Factors			
Sex of HHH				
Male		0.97(0.82,1.04)		1.01(0.84,1.11)
Female		1	1	1
Age of HHH				
<30		0.97(0.94,1.01)		0.96 (0.20,2.34)
30-40		0.57(0.35,2.02)		1.49(0.13,2.41)
41-54		0.43(0.22,0.61)		1.17(0.86,1.59)
>54		1	1	1
Educational sta	tus			
No education		1		1
Primary		3.23 (2.63,3.96)**		2.43(2.00,2.95)*
Secondary		6.36(5.26,7.67)**		2.02(1.61,2.54)*
Higher		8.11 (7.16,9.19)*		4.12(3.35,7.54)**
Wealth index			4	
Poor		1		1
Middle		2.96 (2.34,4.24)**		1.49 (1.21,1.83)*
Rich		5.48 (3.45,5.89)**		3.15(2.55,3.89)**
Having televisi	on			
No		1		1
Yes		4.81(4.16,5.56)**		5.49(4.37,6.89)
Community le	vel factors			· · · · · · · · · · · · · · · · · · ·
Community lev	el education			
Higher			6.50(5.82,7.27)**	3.90(3.15,4.82)*
Lower			1	1
Community-lev	vel media exp	oosure		
Exposed			6.07(5.42,6.81)**	5.61(3.84,10.09)
Unexposed			1	1
Type of residen	ice			
Urban			16.74(11.85, 23.65)**	9.08(6.69,12.33)
Rural			1	1

Tigray		0.50(0.41,0.62)**	0.46(0.37,0.57)**
Afar		0.86(0.67,1.09)	0.67(0.51,0.86)*
Amhara		0.43(0.35,0.53)**	0.40(0.32,0.49)**
Oromia		0.89 (0.72,1.09)	0.90(0.73,1.12)
SNNRP		0.25(0.20,0.31)*	0.28(0.22,0.34)**
Somali		0.33(0.26,0.41)**	0.23(0.18,0.29)**
Benishangul		0.74(0.59,0.94)*	0.63(0.49,0.80)**
Gumuz			
Gambella		0.51(0.41,0.64)**	0.45(0.35,0.57)**
Harari			0.64(0.52.0.80)**
Addis Ababa		1	1
Dire Dawa		0.25(0.21,0.31)**	0.28(0.22,0.35)**
VIF	2.35	2.27	2.05

I= reference, **P-value < 0.001(Adjusted OR), *P-value < 0.05(Adjusted OR), AIC=Akaike's information criteria, BIC=Bayesian information criteria, HHH =household head, HH=household, Model 0 (Null model) was fitted without predictor variables. ; Model 1 is adjusted for individual-level variables. Model 2 is adjusted for community-level variables; Model 3 is the final model adjusted for both individual- and community-level predictors.

Table 3: Measures variation metrics and the model fitness test statistics used for included models

Metrics	Model 0 (Null model)	Model 1	Variables	Model 0 (Null model)
Variance	6.88(5.84,8.10)	2.77(2.30,3.32)	2.04(1.71,2.44)	1.97(1.65,2.35)
MOR	7.07	4.35	3.82	3.78
PCV	Reference	59.74%	26.35%	3.43 %
ICC	0.6765	0.4571	0.3827	0.3745
Model fitness test stati	stics			
AIC	12204.07	11338.86	11610.79	11151.08
BIC	12219.51	11454.67	11734.32	11282.33
Deviance	12,200.0736	11,323.6174	11611.497	11,117.0824

284 Analysis of spatial heterogeneity

285 Spatial autocorrelation (Moran's I)

All EDHS were clustered in obtaining better sanitation facilities through Ethiopia, according to global Moran's I spatial autocorrelations positive z-scores (with the z-scores of 2005 EDHS

To hygienically isolate human excreta from human touch, which causes many infectious diseases, improved sanitation facilities must be accessible in a sustainable and fair manner [42]. This study's primary goal was to examine, using four consecutive EDHS datasets, the spatiotemporal variation and factors linked to improved sanitation facilities that are accessible in Ethiopia. According to these findings, the percentage of households with access to improved sanitation facilities was 20.46% in EDHS 2005, 25.61% in EDHS 2011, 25.86% in EDHS 2016, and 27.45% in EDHS 2019. The rise from 2011 to 2016 was only 0.25%, but the increase from 2005 to 2011 was 5.15%.

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2.374393, 2011 EDHS 7.067996, 2016 EDHS 8.9374285, and 2019 EDHS 36.511348) (Figures

All EDHS in Ethiopia showed the same trend in the spatial distribution of improved sanitation facilities, according to hot and cold spot analysis. The percentage of EDHS that had access to improved sanitation was much lower in the majority of the country, according to the numbers below, and it was higher only in Addis Ababa and Dire Dawa (Figures 6, 7, 8, 9).

The study used spatial Kriging interpolation analysis to determine which parts of the country had less improved sanitation accessibility. As illustrated in the figures below, the red color denotes areas of the country (Addis Ababa and Dire Dawa) with greater access to improved sanitation facilities, while the green color (the majority of the country) indicates areas with lower access

Using multilevel and geographical analysis techniques on Ethiopia's 2005-2019 EDHS datasets, the studies are unique in their thorough investigation of geographic variances and temporal changes in sanitation facilities. Their thorough investigation into the ways in which access to sanitation infrastructure has changed over time and differed among Ethiopia's many regions has produced a fresh contribution by illuminating hitherto unseen trends and inequalities. In order to reduce inequities and enhance overall sanitation access in Ethiopia, this research highlights locations for focused interventions and offers insightful information about the dynamic nature of

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These results indicate that, between 2005 and 2019. Ethiopia's access to better sanitation facilities improved at relatively modest steady rates. This outcome is consistent with other research showing that certain nations have made significant strides toward SDG 6, while others look to be stuck at low levels of sanitation coverage with little or no development [43]. Such setback with little or no development levels of access to improved sanitation facilities is the experience of developing countries including Ethiopia [44]. The construction of sanitation facilities may receive less attention from the government and non-governmental organizations because of international environmental change, poverty, and the nation's instability brought on by the trauma of the civil war. This result is in line with previously conducted research conducted global [33, 45-49]. Based on four EDHS datasets, the geographical analysis's results for Global Moran's

autocorrelation, hotspot, cluster, and Kriging revealed significant differences in Ethiopia's access to better sanitation services. Among other regions of the nation, Addis Ababa and Dire Dawa were identified as high hot spots for improved sanitation facilities based on the findings of the Kriging analysis and hot spot analysis conducted in all EDHS. This result demonstrated that access to better sanitation facilities varies significantly by region across the nation. It ran counter to aim 6.2 of the 2030 Sustainable Development Goals, which is to "end open defecation and provide access to adequate and equitable sanitation for all"[50]. This variation could be the difference in economic growth, overpopulation growth, unplanned urbanization, and inaccessibility of infrastructure, government overload towards other burning daily tasks, socio-political instability, awareness, and adaptability towards sanitation facilities.

The household head's educational level, television ownership, and wealth index were individual level predictors linked to access to better sanitation facilities, while community-level predictor
 variables included education, media exposure, residence type, and region.

Household heads with higher levels of education were more likely to have access to better sanitary facilities than heads with lower levels of education. Ethiopia, Kenya, West and Central Africa, Bangladesh, Benin, and Vietnam have all conducted research that corroborate this conclusion [51-54]. The community with higher education accessed improved sanitation facilities than part of the community with lower education. This finding was in line with other previous studies conducted in different parts of the world [23, 55, 56]. Other possible explanation for this discrepancy is that more people that are educated may be aware of the link between better sanitary facilities and

health. If so, compared to household heads with lower educational background, they are excited tohave these sanitation services.

Access to better sanitary facilities was correlated with wealth status in a proportionate manner. Compared to the poorest homes, wealthy and middle-class households were more likely to have access to better sanitary facilities. The research conducted in Ghana, Benin, Vietnam, and Eswatini supports this conclusion [52, 57-59]. This discrepancy may result from the development of better sanitation facilities like septic tanks and pour-flush toilets; the impoverished may find it difficult to afford slab pit latrines and composting toilets.

When all other factors were held constant, families with television had a higher chance of having access to better sanitary facilities than those without. This may be because residents spent a lot of time watching television, which serves as a visual information source about topics like how better cleanliness can prevent the spread of disease. The other statistically significant predictor of access to better sanitation facilities at the community level was media exposure. In Ethiopia, householders who were exposed to community-level media—whether it was radio, television, or both—were more likely to have access to better sanitation. This result was consistent with earlier research carried out in Ethiopia [22, 23], and sub-Saharan Africa [60].

Compared to households in rural areas, urban households are more likely to have access to better sanitation services. A prior Ethiopian study that showed Ethiopia's rural communities are severely trailing behind in the battle to achieve SDGs supported this issue 6.2 [43] and the other study done in Vietnam [57]. Different amounts of improved sanitation facilities were available to households located in different parts of Ethiopia. Addis Ababa, the capital, was better to the other parts of the country. This finding is aligns with the studies done in Kenya [61], Nepal [62] and WHO, UNICEF, 2019 report [63] which indicated that persist disparities in access to WASH services in rural versus urban settings. This discrepancy could be explained by the fact that Addis Ababa serves as both the nation's capital and the headquarters of the Africa Union, providing access to better infrastructure, including sanitary facilities. Low socioeconomic position, regional sociopolitical instability, ignorance, and a lack of ability to adjust to sanitary facilities could all be contributing factors[64].

The self-report nature of data collection, which leads to interviewer bias, social acceptability bias,

376 recall bias and incompleteness of the recent mini demographic health survey (EDHS 2019), could

- be potential sources of errors and the limitations of this study.

¹¹₁₂ 379 **Conclusion**

According to the study's general findings, Ethiopia's access to sanitary facilities has gradually increased over time. Additionally, there was geographical variation in the country's accessibility of improved sanitation facilities that was statistically significant. To achieve the suggested goal, the rate of advancement in universal access to sanitary facilities (SDG 6.2) in 2030 should be accelerated. The following parameters were statistically linked to the accessibility of sanitation facilities in Ethiopia: region, type of habitation, wealth index, community-level education, community-level media exposure, educational status, and television viewing. This study recommended that local and international organizations focus on solutions that allow for the advancement of universal access to sanitary facilities, particularly in developing nations.

30 389 Abbreviations31

AIC: Akaike's Information Criterion, AOR: Adjusted Odds Ratio, CI: Confidence Interval, DHS:
 Demographic and Health Survey, EAs: Enumeration Areas, EDHS: Ethiopian Demographic and
 Health Survey, ICC: Intra Class Correlation, MOR: Median Odd Ratio, PCV: Proportional Change
 in Variance

40 394 **Declarations**

42 395 **Ethics approval and consent to participate**

This study was based on secondary data from the Ethiopian Demographic and Health Survey and secured the permission letter from the main Demographic Health and Survey. Permission for data access was obtained from a major Demographic and Health Survey through an online request at (https://www.dhsprogram.com/data/dataset admin/login main.cfm.). Participant consent was not directly obtained since authors used secondary data.

401 Patient and Public Involvement
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54 402 Not applicable.

1 2						
- 3 4	403	Consent for publication				
4 5 6	404	Not applicable.				
7 8 9 10	405	Availability of data and materials				
	406	This research was done using a publicly available dataset found at				
11 12	407	https://www.dhsprogram.com/data/dataset_admin/login_main.cfm after approval from Data				
 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 	408	Archivist of the Demographic and Health Surveys (DHS) Program.				
	409	Competing interests				
	410	There is no any competing interest.				
	411	Funding				
	412	The authors have not received any specific grant for this research from public, commercial, or not-				
	413	for-profit funding agencies				
	414	Authors' contributions				
	415	JA Engaged in data curation. JA Conducted the statistical analysis. JA, MT, and WM involved in				
	416	investigation of the study. JA and WM had full access to all the data in the study and take				
	417	responsibility for the integrity of the data and the accuracy of the data analysis. JA, MT, and WM				
	418	done validation and visualization. JA and WM conducted the write-up and drafted the manuscript.				
	419	All authors involved in review & editing. JA is responsible for the overall content as guarantors.				
	420	Acknowledgments				
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40 41	422	data and shape files for this study.				
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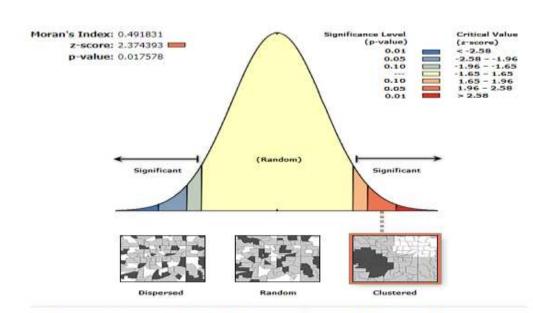
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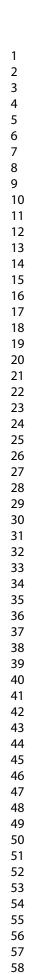




Given the z-score of 2.37439300313, there is a less than 5% likelihood that this clustered pattern could be the result of random chance.

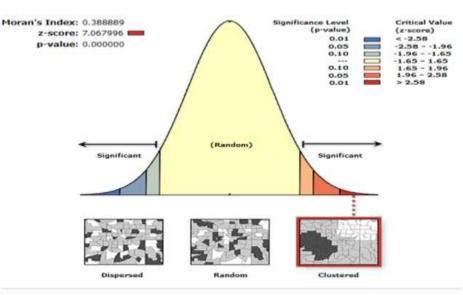
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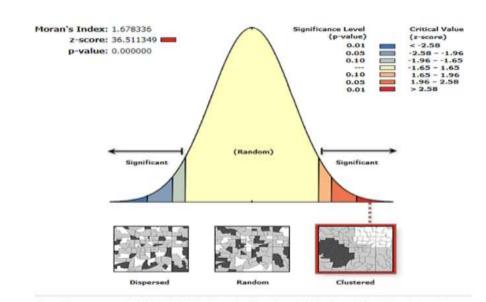
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Given the 2-score of 7.06799640417, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

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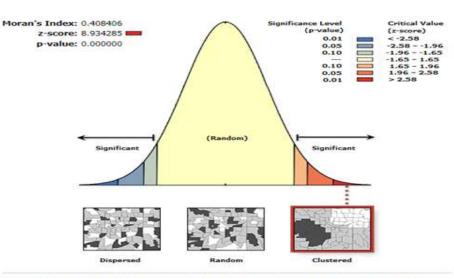


Given the z-score of 36.5113487033, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

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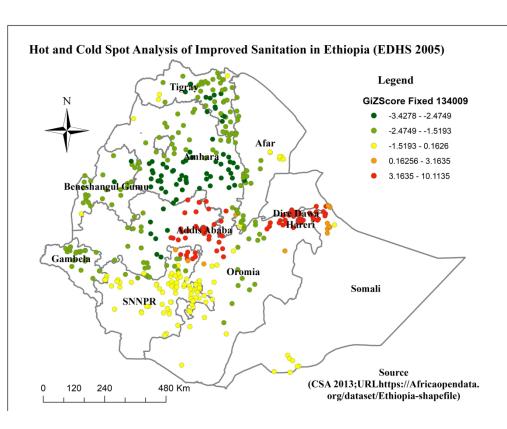
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Given the z-score of 8.93428534383, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

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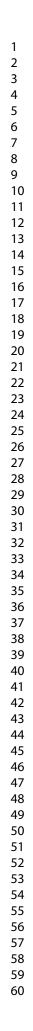


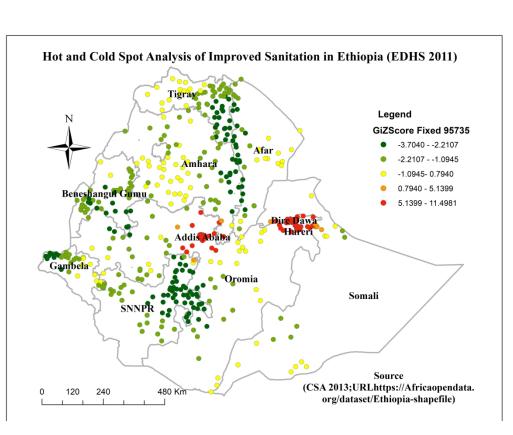
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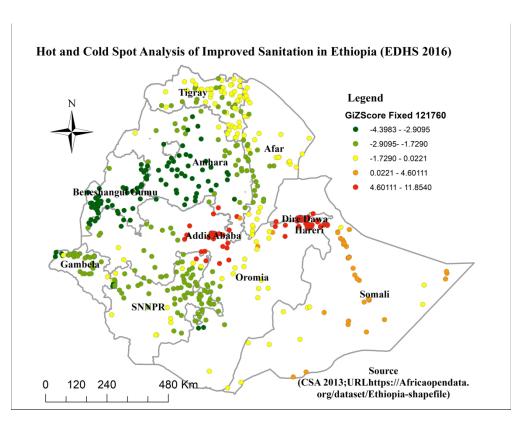
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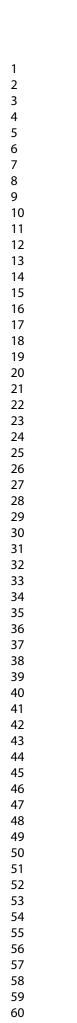


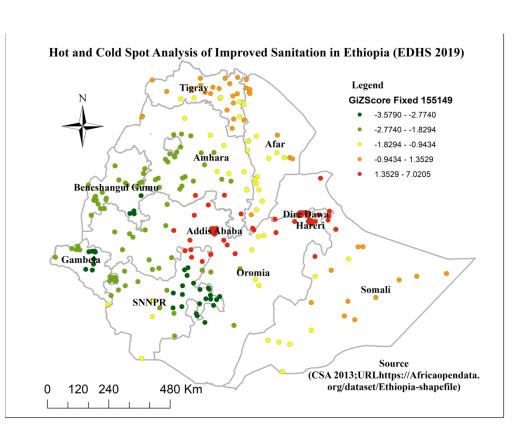
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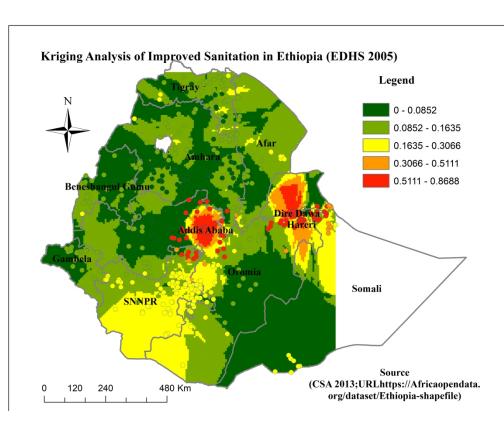
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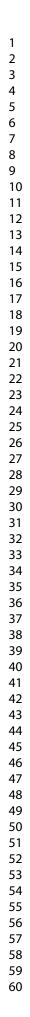


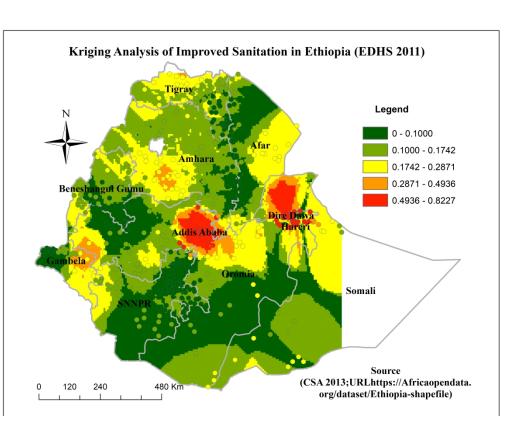


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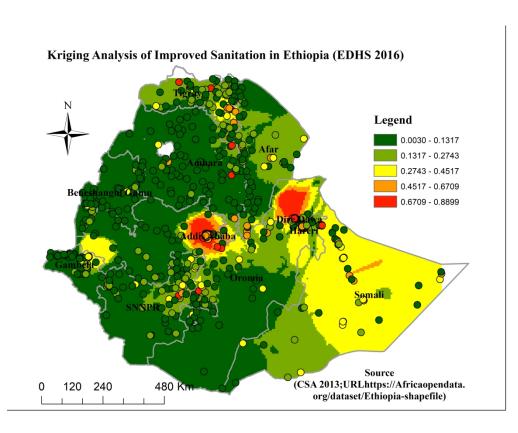


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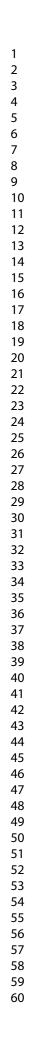


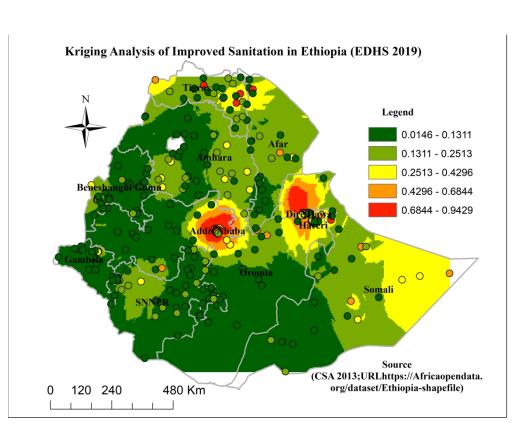


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