Bayesian conditional autoregressive models to assess spatial patterns of diarrhoea risk among children under the age of 5 years in Mbour, Senegal

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Abstract

Diarrhoeal diseases remain a major public health problem, causing more than half a million child deaths every year, particularly in low- and middle-income countries (LMICs). Despite existing knowledge on the aetiologies and causes of diarrhoeal diseases, relatively little is known about its spatial patterns in LMICs, including Senegal. In the present study, data from a cross-sectional survey carried out in 2016 were analysed to describe the spatial pattern of diarrhoeal prevalence in children under the age of 5 years in the secondary city of Mbour in the south-western part of Senegal. Bayesian conditional autoregressive (CAR) models with spatially varying coefficients were employed to determine the effect of sociodemographic, economic and climate parameters on diarrhoeal prevalence. We observed substantial spatial heterogeneities in diarrhoea prevalence. Risk maps, stratified by age group, showed that diarrhoeal prevalence was higher in children aged 25-59 months compared to their younger counterparts with the highest risk observed in the north and south peripheral neighbourhoods, especially in Grand Mbour, Médine, Liberté and Zone Sonatel. The posterior relative risk estimate obtained from the Bayesian CAR model indicated that a unit increase in the proportion of people with untreated stored drinking water was associated with a 29% higher risk of diarrhoea. A unit increase in rainfall was also associated with an increase in diarrhoea risk. Our findings suggest that public health officials should integrate disease mapping and cluster analyses and consider the varying effects of sociodemographic factors in developing and implementing area-specific interventions for reducing diarrhoea.

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See online Appendix for additional tables.

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Introduction

Diarrhoea remains an important public health problem that is associated with high childhood mortality and morbidity, particularly in low- and middle-income countries (LMICs). In 2016, diarrhoea was the eighth leading cause of death among all ages and the fifth leading cause of death among children under the age of 5 years (GBD 2016 Diarrhoeal Disease Collaborators, 2018). Although the number of deaths due to diarrhoea among children under the age of 5 years decreased by an estimated 40.6% between 2007 and 2017, it is still estimated that, in 2017, more than half a million children of this age group died due to diarrhoea (GBD 2017 Causes of Death Collaborators, 2018). Diarrhoea-related morbidity has also declined over the past several years (Fischer Walker *et al*., 2012; GBD Diarrhoeal Diseases Collaborators, 2017). There are nearly 1.7 billion episodes of diarrhoea globally every year (Walker *et al*., 2013; WHO, 2017). Most of diarrhoea-related deaths are attributable to unsafe water, inadequate sanitation and lack of personal hygiene (Black *et al*., 2003; GBD Diarrhoeal Diseases Collaborators, 2017). Indeed, in a comprehensive review of the literature, the World Health Organization

(WHO) estimated that 58% of all cases of diarrhoea in LMICs could be attributed to inadequate drinking water (34%), sanitation (19%) and hygiene (20%) (Prüss-Üstun *et al*., 2014).

In Senegal, diarrhoeal diseases continue to cause considerable mortality and morbidity. The highest burden in terms of disability-adjusted life years (DALYs) among children under the age of 5 years is still caused by diarrhoeal diseases. Even though the burden of diarrhoeal diseases decreased by 6% between 1990 and 2016 across Senegal, it is still responsible for 7% of all child deaths and an estimated 325,335 DALYs (13,776 DALYs per 100,000 children under the age of 5 years) (GBD 2015 DALYs and HALE Collaborators, 2016; Institute for Health Metrics and Evalutation, 2016). In a recent study conducted in the secondary city of Mbour, the reported diarrhoeal prevalence at household level among children under 5 years of age was 26.0% (Thiam *et al*., 2017a). This high burden of diarrhoea is reported despite improvement in access to drinking water and sanitation.

Previous studies in Senegal have mainly focused on clinical features of diarrhoea and looked at single geographic units (Sambe-Ba *et al*., 2013; Sire *et al*., 2013). Hence, there is an important knowledge gap with respect to the spatial patterns of diarrhoea, because prior studies did not identify existing areas of priority for intervention. It is important to note that diarrhoea morbidity varies across geographical areas; some areas are likely to sustain high morbidity over time due to unplanned rapid urbanisation without improvement on essential amenities (*e.g.* access to clean water and improved sanitation), which do not meet the demands of the rising population (Osei and Stein, 2017a). Hence, it is crucial to identify areas with high risk of diarrhoea, in order to assist decision makers in the spatial targeting of interventions and monitor progress over time. Since children are the most vulnerable group to suffer from diarrhoea, information on age-specific patterns are important to meet the Sustainable Development Goal 3 (SDG 3) that is to ensure healthy lives and promote wellbeing for all at all ages.

This paper aims to map the spatial pattern of diarrhoeal prevalence among children under the age of 5 years in the secondary city of Mbour, located in the south-western part of Senegal. Our paper complements prior research pertaining to knowledge, attitudes and practices of diarrhoea in this urban setting of Senegal (Thiam *et al*., 2019). By using a Bayesian conditional autoregressive (CAR) modelling approach, we specifically assess the effect of sociodemographic, economic and climatic factors that might govern diarrhoea morbidity.

Materials and Methods

Ethical approval

This study received ethical approval from the national research ethics committee (Comité National d'Ethique de la Recherche-CER) of Senegal (reference no.: 0l06/2015/CER/UCAD). An interview was conducted only if the respondent provided his or her informed consent. Given the high illiteracy rate of mothers and caregivers of under 5-year-old children in Mbour, we aimed for verbal rather than written informed consent. The interviewer signed his or her name attesting to the fact that he/she read the consent statement to the respondent.

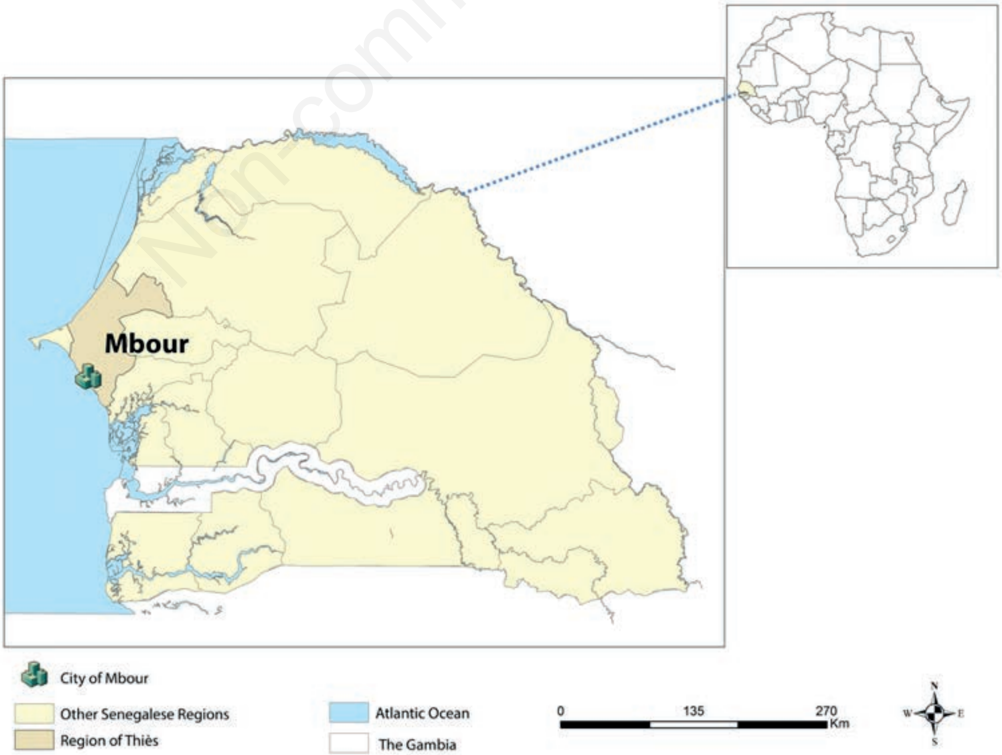

Figure 1. Map showing the administrative region and the location of Mbour in Senegal.

Study area and design

The study was conducted in the secondary city of Mbour, which is located in the south-western part of Senegal in the Region of Thiès (Figure 1). Mbour consists of 25 neighbourhoods. A cross-sectional survey was carried out in September and October 2016, covering all 25 neighbourhoods. The outcome of interest was diarrhoeal disease case report among under 5-year-old children in the sampled household. A detailed description of the activities performed during the cross-sectional survey has been published elsewhere (Thiam *et al*., 2017b).

Sociodemographic, economic and climate data

As diarrhoea transmission is known to be influenced by several factors, including water, sanitation and hygiene (WASH), climatic, sociodemographic and economic factors, we obtained sociodemographic and economic covariates from a survey questionnaire. We constructed the following sociodemographic variables as risk factors of diarrhoea: unsafe drinking water source (*udws*), untreated stored drinking water (*usdw*), unsafe liquid waste disposal (*ulwd*) and unsafe solid waste disposal (*uswd*). We defined the socio-environmental variables as follows: i) *udws* as the proportion of the neighbourhood's surveyed households that lack access to pipe-borne water (either in dwellings, outside dwellings or public standpipes); ii) *usdw* as the proportion of the neighbourhood's surveyed households that do not treat their stored drinking water; iii) *ulwd* as the proportion of the neighbourhood's surveyed households that dispose liquid waste in the street; and iv) *uswd* as the proportion of the neighbourhood's surveyed households that do not have a waste bin. An economic status variable was derived from principal component analysis (PCA) as a weighted sum of household assets that was included in the analysis as a continuous covariate. A detailed description of the household assets used to run the PCA has been described in a previous paper (Thiam *et al*., 2017a).

Climatic covariates were obtained from readily available remote sensing sources (Table 1). The climatic factors used in our analysis are land surface temperature (LST) at day and night, altitude and rainfall covering the survey period (*i.e.* September and October 2016). LST and altitude data were extracted at the unit of the neighbourhood from the Moderate Resolution Imaging Spectroradiometer (MODIS) database. Rainfall estimates data were downloaded from the Africa Data Dissemination Service database. Climatic covariates were included in the analysis as continuous covariates. The data were aggregated by neighbourhood units and the geographical scale of the analyses considered the entire 25 neighbourhoods of Mbour.

Bayesian conditional autoregressive modelling approach

First, a preliminary binomial logistic regression of diarrhoea cases among children under the age of 5 years was performed to select covariates. Four climatic variables (*i.e.* $\mathrm{LST}_{\mathrm{Day}}$, $\mathrm{LST}_{\mathrm{Night}}$, rainfall and altitude) and four sociodemographic and economic variables (*i.e. udws*, *usdw*, *ulwd* and *uswd*) were included as covariates. Second, we fitted three separate logistic regression models to estimate the effect of sociodemographic, economic and climatic parameters on diarrhoea morbidity in our target group of children using a Bayesian framework. The first model included only climatic covariates; the second model included sociodemographic and economic covariates, whereas the third model contained all of the components of models 1 and 2, as well as a spatially structured random effect. The spatially structured random effect was formulated assuming a CAR model prior distribution (Cressie, 2015; Ssempiira *et al*., 2017), which introduces a neighbours-based spatial structure random effect for the regression coefficients (Bivand *et al*., 2013). To adjust for spatial correlation present in diarrhoea data due to similar exposure effect in neighbouring areas, cluster-specific random effects were added to each model to account for unknown or unmeasured risk factors by introducing an extra source of variability into the model. This approach was employed to generate spatial weights matrix, which assigned value 1 to areas that share borders and 0 otherwise. More specifically, for the third model, it was assumed that Y_{ij} is a binary outcome taking value 1 or 0 if a child i at neighbourhood s_j had diarrhoea in the 2 weeks prior to the survey. Y_{ij} is assumed to follow a Bernoulli distribution $Y_{\mathrm{ij}} \sim Bn\ (\mathrm{N}_{\mathrm{ij}}, P_{\mathrm{ij}})$ and is related to its predictors using a logistic regression model, as follows (Eq. 1):

$$logit(p_{ij})=\beta_0+\sum_{k=1}^{k} \beta_k\ X_{ij}^{k}+\phi_j+\omega_i\,, \qquad \text{Eq. 1}$$

where p_{ij} is the diarrhoea case at neighbourhood i, s_j of having diarrhoea (*i.e.* an offset to control for population size), and $\beta = (\beta_0, \beta_1,..., \beta_k)$ is the vector of k regression coefficients. Spatial dependence is introduced by adding location-specific random effects ϕ_j at every surveyed location (s_j). Non-spatial variation is estimated by the random effects $\omega_i \sim N\ (0,\ \sigma_w^2)$ for the unstructured spatial effect assumed independent and normally distributed with mean 0 and variance σ_w^2 for the spatially structured random effect. A CAR prior distribution was employed to model the spatially structured random effect. A flat prior distribution was specified for the intercept, while a non-informative normal prior distribution was used for the coefficients. The prior for the precision of the spatially structured random effects was specified using non-informative gamma distribution with shape and scale parameters equal to 0.5. An initial burn-in of 1,000 iterations was run, and these iterations were discarded. Subsequent blocks of 250,000 iterations were run and checked for convergence. Convergence was assessed by visual inspection of posterior density and history plots. All model parameters were stored and summarised for the analysis. In all analyses, a level of 0.05 was adopted to indicate statistical significance as indicated by a 95% Bayesian credible interval (BCI) for the relative risk excluding 1. Continuous covariates were standardised for

Table 1. Remote sensing data sources, reporting period and spatial resolution.

Remote sensing data source	Type	Period	Spatial resolution
MODIS	$\mathrm{LST}_{\mathrm{Day}}$	September/October 2016	1×1 km
	$\mathrm{LST}_{\mathrm{Night}}$	September/October 2016	1×1 km
USGS/decadal RFE	RFE	September/October 2016	80×80 km
SRTM-Altitude	Altitude	September/October 2016	90×90 km

MODIS, Moderate Resolution Imaging Spectroradiometer (http://modis.gsfc.nasa.gov); USGS/decadal RFE, United States Geographical Survey/decadal rainfall estimates (http://earlywarning.usgs.gov); SRTM-Altitude, Shuttle Radar Topography Mission (http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v41); LST, land surface temperature.

addressing correlation between covariates. Parameter estimates were summarised using posterior medians and the corresponding 95% BCI. For epidemiological interpretation, model estimates were exponentiated to produce odds ratios (ORs).

Model fits and parameter estimation were performed using a Bayesian framework and Markov chain Monte Carlo (MCMC) estimation. Model specification was completed by assigning gamma prior distributions to model parameters. Data analysis was carried out in STATA version 14 (StataCorp; College Station, TX, USA). OpenBUGS version 3.2.3 (Imperial College and Medical Research Council; London, UK) was used to perform model fit. The maps were produced using ArcGIS software version 10.5 (ArcMap, ESRI; Redlands, CA, USA).

Results

Summary of sociodemographic and WASH conditions of the surveyed households

A total of 1,083 children under the age of 5 years from 761 households participated in the cross-sectional survey conducted in Mbour, between September and October 2016. Sociodemographic and economic characteristics of the surveyed households and WASH conditions in the four stratified zones of Mbour are provided as supplementary files (Appendix Tables A1 and A2).

Distribution of the observed diarrhoeal prevalence and the sociodemographic covariates

The observed diarrhoea prevalence in children under the age of 5 years, stratified by age group, zone and neighbourhoods, are summarised in Table 2. The number of children among those surveyed who reportedly had diarrhoea during the 2 weeks preceding the survey was mapped by neighbourhood areas to illustrate the distribution patterns of the observed prevalence (Figure 2).

Table 2 shows that the overall observed diarrhoea prevalence of 33.9% varied between 20.0% (neighbourhood of Grand Mbour) and 57.9% (neighbourhood of Baye Deuk). Among the youngest age group (children aged below 12 months), the observed diarrhoeal prevalence was 31.6%, varying between 8.6% (neighbourhood of Zone Résidentielle) and 42.9% (neighbourhood of Mbour Sérère Souf). For children aged 12-24 months, the overall prevalence of diarrhoea was 40.0%, varying between 14.3% (neighbourhood of Mbour Sérère Souf) and 57.9% (neighbourhood of Baye Deuk). For children aged 36-59 months, the observed prevalence was 29.3%, varying between 21.0% (neighbourhood of Baye Deuk) and 53.1% (neighbourhood of Medine). The geographical distribution of the observed prevalence, stratified by age group, is illustrated by the maps displayed in Figure 2.

The spatial distribution of the model-based estimation of diarrhoea risk from the posterior estimates, adjusted for spatially random effect, spatial correlation and varying coefficient effects, are shown in Figure 3. Most of the neighbourhoods in Mbour exhibit

Table 2. Summary of the observed diarrhoeal prevalence in children under the age of 5 years, stratified by age group, zone and neighbourhood in Mbour in late 2016.

Zone	Neighbourhood	Observed diarrhoeal prevalence in children aged			
		<5 years (%)	<12 months (%)	12-24 months (%)	36-59 months (%)
UCA		38.3	21.1	38.3	40.5
	Château d'eau Nord	30.6	19.4	38.7	41.9
	Château d'eau Sud	27.6	31.0	27.6	41.4
	Onze Novembre	33.3	20.5	43.6	35.9
	Tefess	57.1	32.1	39.3	28.6
	Golf	38.5	15.4	38.5	46.2
	Zone Residentielle	54.3	8.6	42.9	48.6
	Mbour Serère Souf	28.6	42.9	14.3	42.9
PCA		34.8	22.5	39.5	37.9
	Darou Salam	30.6	16.1	40.3	43.5
	Diamaguene 1	35.6	19.2	47.9	32.9
	Diamaguene 2	34.7	27.7	35.6	36.6
	Baye Deuk	57.9	21.1	57.9	21.1
	Santessou	31.8	18.2	40.9	40.9
	Thiocé Est	32.4	18.9	36.5	44.6
	Thiocé Ouest	36.4	33.3	33.3	33.3
	Mbour Toucouleur	32.3	22.6	41.9	35.5
	Mbour Serère Kaw	36.4	27.3	30.3	42.4
NPA		26.9	15.5	36.2	48.3
	Grand Mbour	20.0	12.5	38.8	48.8
	Liberté	31.6	10.5	36.8	52.6
	Médine	26.6	15.6	31.3	53.1
	Santhie	31.4	27.5	37.3	35.3
SPA		37.2	13.1	42.3	44.5
	Gouye Mouride	32.4	10.8	37.8	51.4
	Oncad	34.6	15.4	46.2	38.5
	Mbour Maure	33.3	22.2	44.4	33.3
	Zone Sonatel	46.2	10.3	41.0	48.7
Overall		33.9	31.6	40.0	29.3

UCA, Urban Central Areas; PCA, Peri-Central Areas; NPA, Northern Peripheral Areas; SPA, Southern Peripheral Areas.

similar patterns, except four neighbourhoods with diarrhoea risk above 40%.

A summary of the sociodemographic covariates can be seen in Table 3. Briefly, the proportion of the surveyed household without safe drinking water was 41.7%, varying from 0% in Mbour Sérère Souf to 100% in Baye Deuk and Gouye Mouride. About 69% of the surveyed households do not treat their stored drinking water; this proportion varied from 28.9% in Médine to 85.0% in Tefess. The proportion of the surveyed household without access to safe liquid waste disposal ranged from 4.2% in Thiocé Ouest to 91.7% in Zone Residentielle and Mbour Sérère Kaw. The proportion of the surveyed household without access to proper solid waste disposal ranged from 0% to 100%.

Posterior estimates of the effect of sociodemographic, economic and climatic factors

The results from the Bayesian CAR models are presented in Table 4. To facilitate interpretation of the effect of sociodemographic and climatic factors on diarrhoea risk, all parameter estimates were exponentiated. In model 1, association of diarrhoea prevalence with altitude, rainfall and LST_{day} were positive; however, none of these associations were of statistical importance. In model 2, untreated stored drinking water was significantly associated with diarrhoea prevalence in children. A unit increase in the proportion of people who do not treat their stored drinking water increases diarrhoea risk by 22%, suggesting that diarrhoea risk for people using untreated stored drinking water is 22% higher than those who use treated stored drinking water. The results from model 2 also indicate a significant association between diarrhoea risk and economic status. No multiplicative effects were observed for *udws* and *uswd,* meaning that differences in sources of drinking water and wastewater disposal could not account for the observed variation in diarrhoea risk across neighbourhoods. In model 3, rainfall, LST_{day}, untreated stored drinking water, unsafe wastewater disposal and economic status were positively associated with diarrhoea prevalence in children in Mbour.

Discussion

This study aimed to explore and map the spatial pattern of diarrhoeal prevalence among children under the age of 5 years in the secondary city of Mbour, Senegal. Risk profiling was done at the unit of the neighbourhood (n=25) and we specifically determined the effect of sociodemographic, economic and climatic factors. We employed a Bayesian framework with CAR models. The study is the first effort to explore the spatial patterns of diarrhoea in an urban setting of Senegal. The assumptions in the modelling approach are that the effect of sociodemographic, economic and climatic factors in neighbouring areas should be similar; whereas the effect should be increasingly dissimilar the further away areas are located from each other.

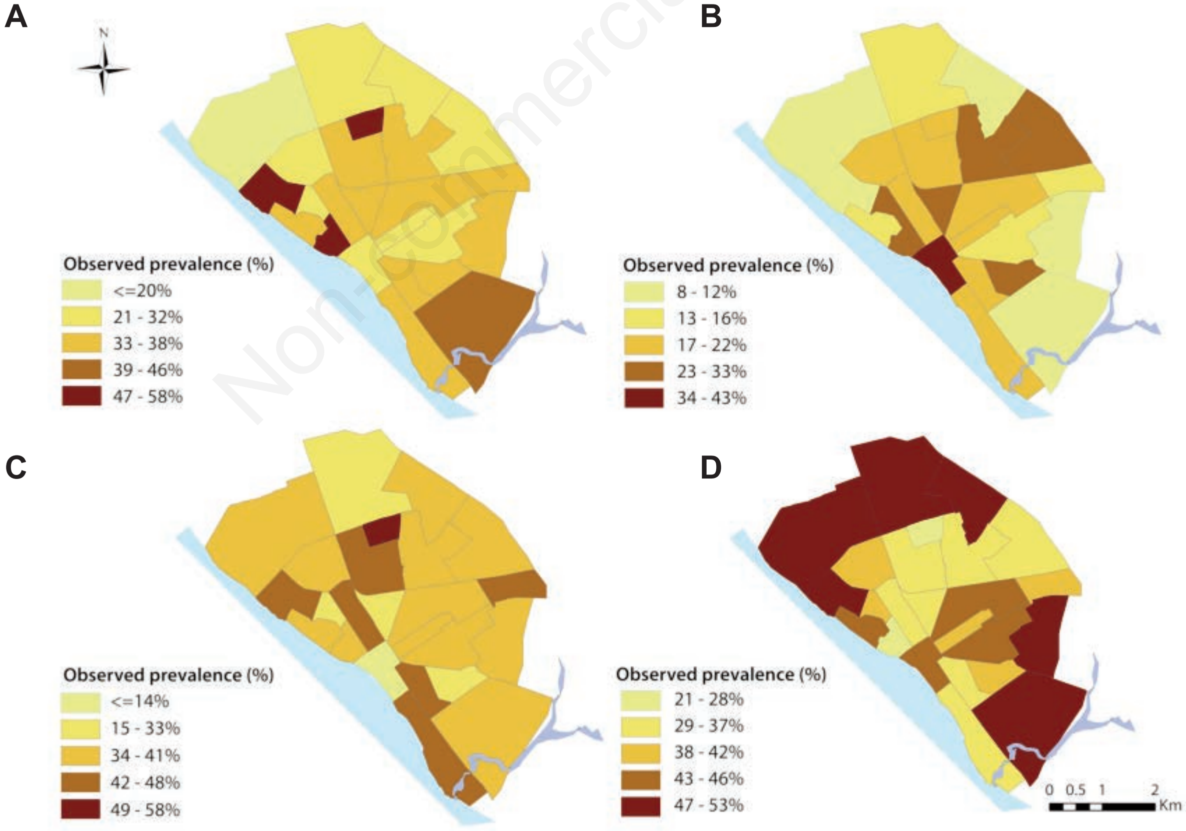

Figure 2. Spatial distribution of the observed diarrhoea prevalence in children under the age of 5 years in Mbour in 2016. Overall observed prevalence (A); observed diarrhoea prevalence among children aged 0-11 months (B), observed prevalence among children aged 12-24 months (C) and observed prevalence among children aged 25-59 months (D).

Table 3. Summary of the sociodemographic covariates, stratified by zone and neighbourhood in Mbour in late 2016.

Zone	Neighbourhood	Proportion *udws*[*] (%)	Proportion *usdw*[°] (%)	Proportion *ulwd*[#] (%)	Proportion *uswd*[§] (%)
UCA		16.3	77.1	60.1	85.6
	Château d'eau Nord	4.8	76.2	81.0	95.2
	Château d'eau Sud	26.3	79.0	63.2	100.0
	Onze Novembre	7.1	78.6	39.3	78.6
	Tefess	20.0	85.0	10.0	80.0
	Golf	57.1	78.6	57.1	100.0
	Zone Residentielle	16.7	70.8	91.7	83.3
	Mbour Serère Souf	0.0	60.0	60.0	0.0
PCA		28.9	75.8	76.7	93.2
	Darou Salam	41.9	81.4	88.4	90.7
	Diamaguene 1	22.2	83.3	72.2	90.7
	Diamaguene 2	27.9	76.5	88.2	97.1
	Baye Deuk	100.0	60.0	86.7	93.3
	Santessou	5.6	66.7	83.3	100.0
	Thiocé Est	17.9	71.4	76.8	94.6
	Thiocé Ouest	8.3	79.2	4.2	91.7
	Mbour Toucouleur	20.0	65.0	80.0	90.0
	Mbour Serère Kaw	50.0	79.2	91.7	87.5
NPA		59.5	56.2	71.9	88.1
	Grand Mbour	40.7	66.1	72.9	76.3
	Liberté	78.3	56.5	76.1	95.7
	Médine	82.2	28.9	53.3	93.3
	Santhie	37.1	74.3	88.6	91.4
SPA		88.1	57.4	75.2	92.1
	Gouye Mouride	100.0	60.0	80.0	100.0
	Oncad	92.5	62.5	80.0	97.5
	Mbour Maure	37.5	50.0	75.0	37.5
	Zone Sonatel	85.7	50.0	64.3	92.9
Overall		41.7	68.9	72.0	90.3

udws, unsafe drinking water source; *usdw*, untreated stored drinking water; *ulwd*, unsafe liquid waste disposal; *uswd*, unsafe solid waste disposal. UCA, Urban Central Areas; PCA, Peri-Central Areas; NPA, Northern Peripheral Areas; SPA, Southern Peripheral Areas. [*]Proportion of the surveyed households that do not have access to pipe-borne water (either in dwellings, outside dwellings or public standpipes); [°]proportion of the neighbourhood's surveyed households that do not treated their stored drinking water; [#]proportion of the neighbourhood's surveyed households that dispose wastewater in the street; [§]proportion of the neighbourhood's surveyed households that do not have a proper waste bin.

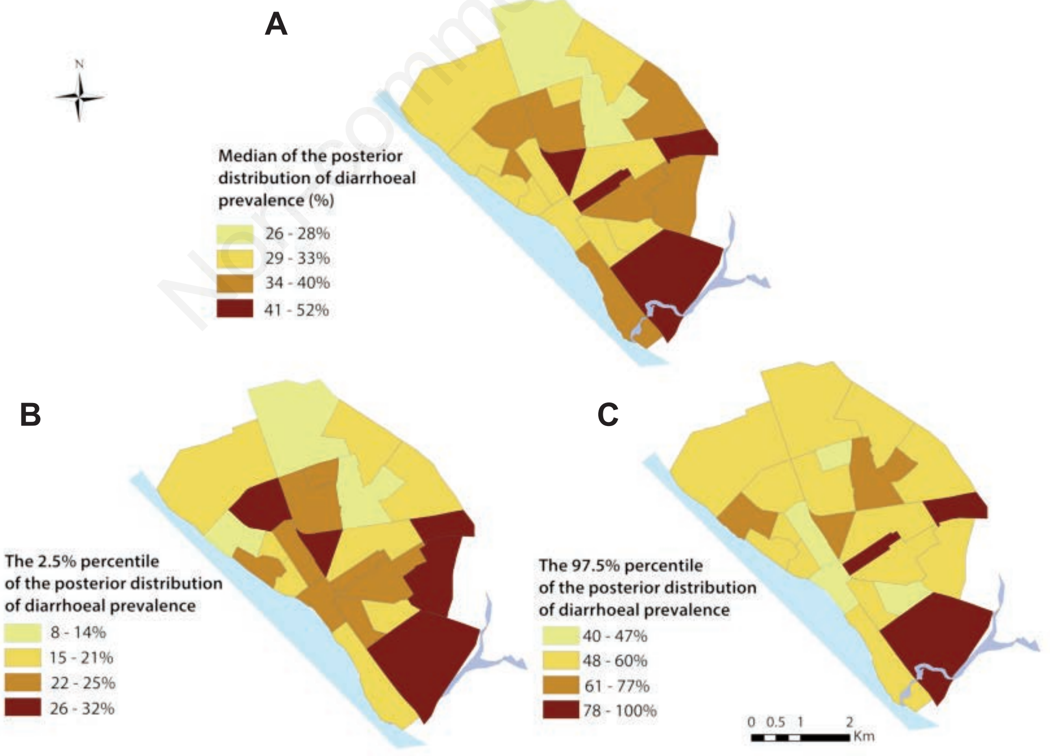

Figure 3. Spatial distribution of the smoothed diarrhoeal prevalence from the posterior median and the 2.5% and 97.5% percentiles. Median (A), 2.5% percentile (B) and 97.5% percentiles (C) of the posterior distribution of diarrhoeal prevalence. Estimations are based on model 3.

The findings from the Bayesian smoothed maps show substantial variation in the spatial distribution of diarrhoea with neighbourhoods of higher and lower than expected risk clustered. This might be explained by wider sociodemographic and economic inequalities between neighbourhoods (Osei and Stein, 2017b). Unsafe treated stored water and the high prevalence of diarrheal disease observed in the city of Mbour near the coastal area could be explained by the presence of many pathogens, which proliferate in brackish river and coastal water environments, along with the presence of higher levels of enteric microorganisms typically found in coastal areas. A similar pattern, with higher incidence of acute diarrhoea and cholera has been observed in India near the coastal areas (Alam *et al*., 2006; Kumar *et al*., 2016). Prior epidemiological studies have shown that people living in close proximity to coastal areas are at higher risk of contracting infectious diseases. This could be due to polluted coastal waters that may run inland during rainy season, leading to higher incidence of diarrhoea (Lipp *et al*., 2002; Rajendran *et al*., 2011; Jayakumar and Malarvannan, 2013).

Our study has several limitations that are offered for consideration. First, the study is based on morbidity data aggregated at a neighbourhood level. That is why we focus on modelling the spatially varying coefficient as realisations of a CAR process produced from the weighting of the burden in the neighbouring areas. Hence, it was not possible to account for local variations in neighbourhood covariate effects through spatially varying coefficients; and therefore we could not estimate neighbourhood-specific relative risk, which relies on point referenced data (Gelfand *et al*., 2003). Disease indices, such as the relative risk of common morbidity, are an important measure of estimate in disease mapping used for comparing neighbourhood health status for spatially explicit planning of health interventions (Osei and Stein, 2017b). Further studies using similarly rigorous statistical approaches as pursued here should map neighbourhood-specific relative risk estimates and determine the spatially varying association between the relative risk and potential risk factors.

Second, due to unavailability of temporal data, this study has also not considered a potential temporal variation of the prevalence of diarrhoea and possible temporal change in the sociodemographic, economic and climatic factors. The identification and understanding of clusters in space and time at neighbourhood level should be considered for future research.

Despite these limitations, the findings of the current study complement our prior research pertaining to the aetiology and local perceptions of diarrhoea in under 5-year-old children in Mbour (Thiam *et al*., 2019). The observed spatial pattern of diarrhoea provides valuable information for health programme managers to design and implement interventions. This spatially explicit information is not only important for the Ministry of Health, but also other ministries responsible for WASH aspects. Indeed, diarrhoea risk areas can, and should, be identified at neighbourhood level to tackle area-specific interventions, which might also be important for the control and prevention of suspected diarrhoea outbreaks.

Conclusions

Our findings revealed that childhood diarrhoea remains a major public health problem in the secondary city of Mbour, Senegal with considerable spatial heterogeneity from one neighbourhood to another. Our findings provide a deeper understanding of the geographical variation of neighbourhood health status and suggest that attention should be paid to children aged 2 years and above in the north and south peripheral neighbourhoods, such as Médine, Liberté, Grand Mbour, Zone Sonatel and Gouye Mouride, which are characterised by a lack of amenities such as availability of safe water source and improved sanitation. In such areas, priority attention would be important on WASH-related interventions in order to prevent and control diarrhoea in under 5-year-old children.

Table 4. Posterior median and 95% Bayesian credible intervals of model 1 (model of diarrhoea risk based on climatic covariates), model 2 (model of diarrhoeal risk based on sociodemographic and economic covariates) and model 3 (model of diarrhoeal risk comprised climatic and sociodemographic and economic covariates).

Model/variables	Model 1 RR (95% BCI)	Model 2 RR (95% BCI)	Model 3 RR (95% BCI)
Climatic variable			
Altitude	1.03 (0.83-1.25)		0.79 (0.63-0.96)*
Rainfall	1.18 (0.89-1.44)		1.40 (1.10-1.74)*
LST_{day}	1.07 (0.89-1.16)		1.07 (0.93-1.27)
LST_{night}	0.91 (0.81-1. 03)		0.82 (0.69-1. 03)
Socioeconomic and environmental factors			
udws		0.96 (0.55-1.45)	0.83 (0.69-1.05)
usdw		1.22 (1.01-1.53)*	1.29 (1.06-1.60)*
ulwd		0.89 (0.78-1.05)	0.96 (0.86-1.12)
uswd		1.03 (0.78-1.30)	1.06 (0.78-1.43)
Socioeconomic status		1.32 (0.77-2.24)	1.95 (1.43-2.54)*

RR, relative risk; BCI, Bayesian credible interval; LST, land surface temperature; *udws*, unsafe drinking water source; *usdw*, untreated stored drinking water; *ulwd,* unsafe liquid waste disposal; *uswd*, unsafe solid waste disposal. *Statistically significant.

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