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Determinants of Maternal Mortality in Edo South Senatorial District, Nigeria

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abstract

Nigeria, like most sub-Saharan African countries, has a high number of maternal deaths during pregnancy, delivery, and post-partum. Each time a woman gets pregnant in Nigeria, she is faced with the probability of dying due to maternal issues. This paper seeks to determine the factors influencing the incidence of maternal mortality associated with four levels (individual, household, medical, and community) among pregnant women in the Southern Senatorial District of Edo State, Nigeria. The respondents comprised of adult women of reproductive age (15–49 years). STATA version 13 was used to conduct multinomial logistic regression for data analysis. The data analysis was carried out using 1546 households in 29 communities in the district. The regression model depicts that maternal mortality outcome is higher in the rural region of the study area. Education, parity, mode of delivery, and history of pregnancy complications are factors influencing maternal mortality in the study area. Rural areas record higher maternal mortality than urban areas. This study recommends that spatially identified factors in the district affecting the best maternal outcome should be addressed, especially in grassroots government intervention programs and policies for overall improvement in living and health standards of the people in the district.

Introduction

All over the world, about 295,000 women die during pregnancy and childbirth, with over 800 women dying daily from pregnancy and childbirth complications. Maternal deaths occur in sub-Saharan Africa (MMR of 553) and South Asia (MMR of 163) despite efforts to reduce maternal deaths (UNICEF, 2019). With global regional progress achieved, there are still reports of alarming levels of maternal deaths in the sub-Saharan region of Africa. Most maternal death is preventable as proven by records depicting vast differences between the richest and poorest countries. The lifetime risk of maternal mortality is 1 in 5,400 in developed nations when compared to 1 in 45 in developing countries. In 2020, the maternal mortality ratio was reported as 302 per 100,000 live births and 147 per 100,000 live births in sub-Saharan Africa and South Asia respectively (Bill & Melinda Gates Foundation, 2021). Countries were committed to the Millennium Development Goals Target 5 (MDG), reducing the number of 1990 maternal deaths (532, 000) by three-quarters by the year 2015. Countries like Nigeria, Central African Republic, Congo, Cameroon, Gambia, and Mauritania made no progress (less than 25 percent) in the reduction of maternal mortality ratio, while India, Sierra Leone, Ghana, Chad, Liberia, and Niger made inadequate progress (greater than 25 percent) toward achieving the MDG goals for maternal mortality (WHO, 2015).

In 2015, the Socio-Demographic Index (SDI) was developed to help produce maternal mortality estimates from international to regional levels. From the Human Development Index and health-related indices, the Socio-Demographic Index (SDI) has been used in several studies to estimate mortality and morbidity (Uriri, 2015; Moradi-Laken et. al, 2017).

Each of the SDI three components (per capita income, average educational accomplishment, and fertility rate) scales from 0–1, while zero represents a negative scenario and 1 is the ideal situation. SDI can be used to predict maternal mortality levels and it identifies prospective countries with the worst and best measures for maternal mortality. This new method measures progress by comparing health indicators with a country's economic development status. Surprisingly, countries like the United States and Russia are doing quite poorly. Although it has been proven that development drives economic growth, it may not determine healthiness of people.

In Western sub-Saharan Africa, Ghana (0.53) has a higher SDI than Nigeria (0.49), Cameroon (0.48) and Benin (0.37). Nigeria is grouped in the low-middle Social Demographic Index cadre based on 2017 values. In 1980, Nigeria's recorded value was 0.28 and it rose to 0.49 in 2017. The worst values in 2015 were observed in countries like Niger (0.19), Burkina-Faso (0.28) and Chad (0.25) (GBD, 2017). Studies in developing countries have identified the social demographic attributes of a population to include: age, sex, education ethnicity/migration background, religion, marital status, type of household/household size, employment/occupation, parity, residence, income, and healthcare autonomy. The negative impact of these attributes depicts poor human development in most countries, especially for pregnant women. The inability to meet these necessities of human life could ultimately lead to maternal deaths. On these bases, various studies were modelled after socio-demographic variables (Ukachi, 2019; Adenyuwa & Mundi, 2020; Bomela, 2020; Zhou et al., 2020).

One of the major global concerns is what the determinants of maternal mortality are. Maternal death determinants have been highly investigated. Reproductive-aged women's exposure to death from maternal causes is due to several factors. Factors of maternal death and morbidity were deduced from comprehensive determinants and correlates. In Pakistan and Eastern Mediterranean countries, determinants ranged from individual, economic, and social to healthcare system-related factors on maternal mortality. Such factors include poverty, poor educational background and lack of empowerment, male dominance, husband absence from home, devaluing of females, family traditions, low neglected status of women, and early marriages (Pakistan medical students [JPMS], 2013). Physical factors highlight the three delay models as well as poor or no transportation and long distance for most rural

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women. Lack of Skilled Birth Attendants (SBA), influence of Traditional Birth attendants (TBAs), and unsafe abortion were listed as human factors, while medical factors cover the identified direct and indirect causes of maternal mortality (Bayati et al., 2016).

Hamal et al. (2020) identified the social determinants of maternal deaths and health care in India. Factors were grouped into structural and intermediate and they were analysed to show association with other health system variables. The use of evidence from other qualitative and quantitative studies in India was incorporated into their study and the findings depict variation amongst factors in states and communities. In rural Tanzania from 2004–2007, Hanson et al. (2015) measured emergency care accessibility, health facilities distance, and cause of mortality by pregnancy-related mortality among women who are within 13 to 49 years. The study applied the multilevel logistic regression on factors influencing pregnancy-related mortality. The study concluded that farther distance to health facilities was one factor influencing high incidences of direct obstetric deaths.

Determinants related to household and community range from enlightened communities, low status of women, educational inequality, occupation, and asset to autonomy amongst others. Bad cultural practices, religious views, and household income influence maternal health utilization, mother's age, height, parity, unsafe abortion among young adolescents, and early marriage and motherhood are associated with high numbers of children amongst other factors that threaten women's lives in Africa. Socio-demographic factors, as well as health-related factors such as malaria, HIV/AIDS, poorly funded and management of healthcare services, weak referral systems, bad roads, bad terrain, lack of skilled health personnel, negative attitudes, and lack of essential drugs and equipment relate to maternal mortality. Healthcare costs and delays directly or indirectly prohibit health facilities utilization (Rogo et al., 2006; John-Abebe & Osirike, 2015; John-Abebe & Osirike, 2020).

In Nigeria, Oyibo et al. (2017) showed that in the area of reproductive health, maternal mortality is a major problem. In Ogun state, community-based research determines the non-medical variables affecting mortality and pregnancy complications for women of reproductive ages. This research identifies determinants of maternal deaths to include challenges and lifestyle behaviours of pregnant women's health care, where they seek delivery services, cost of maternal services, knowledge of complications and place of antenatal, common ailment, place of consultation, family size, place of delivery, cost of ante-natal, and provider of ante-natal care (ANC) assistance (Azuh et al., 2017). Statistically, where consultation took place and who paid for the treatment were the most significant factors influencing maternal mortality. One of the chief impediments to accessing healthcare services is the distance to health facilities. Common ailments such as Malaria/fever, and large family size were other identified correlates.

Several research works carried out in developing nations, especially in sub-Saharan Africa, particularly in Nigeria have revealed that individual, family, and community determinants were positively linked to maternal healthcare behaviour that relates to maternal mortality outcome (Aigbe, 2011; John-Abebe & Osirike, 2015; Anastasia et al., 2017; Machira, 2017, Meh et al. 2019). Every pregnant woman is faced with the risk of dying each time she conceives. These factors range from the periods of prenatal care, and childbirth to postnatal care utilization. Several predictors of maternal mortality in Southern Nigeria include demographic, social, cultural, economic, and health-related. The predicators further include mother's age at birth, age at marriage, education attainment, income, marriage status/type, household size, spouse occupation, family wealth/income, employment/labour force status, religion, place of residence, and the decision in seeking health care (Konwea & Fabamise, 2019; Mahmood, 2021; Woko et al., 2021; Adesina et al., 2022). Other predictors of maternal mortality were also health-related, such as the prevalence of undernourishment, number of ante-natal, delivery outcome, mode of delivery, parity, family planning, booking status amongst others, poor healthcare system, and health-related risk factors (failure of patient, human, technical factors) (Olonade et al., 2019; Chiwah et al., 2020; Olamijulo et al., 2022).

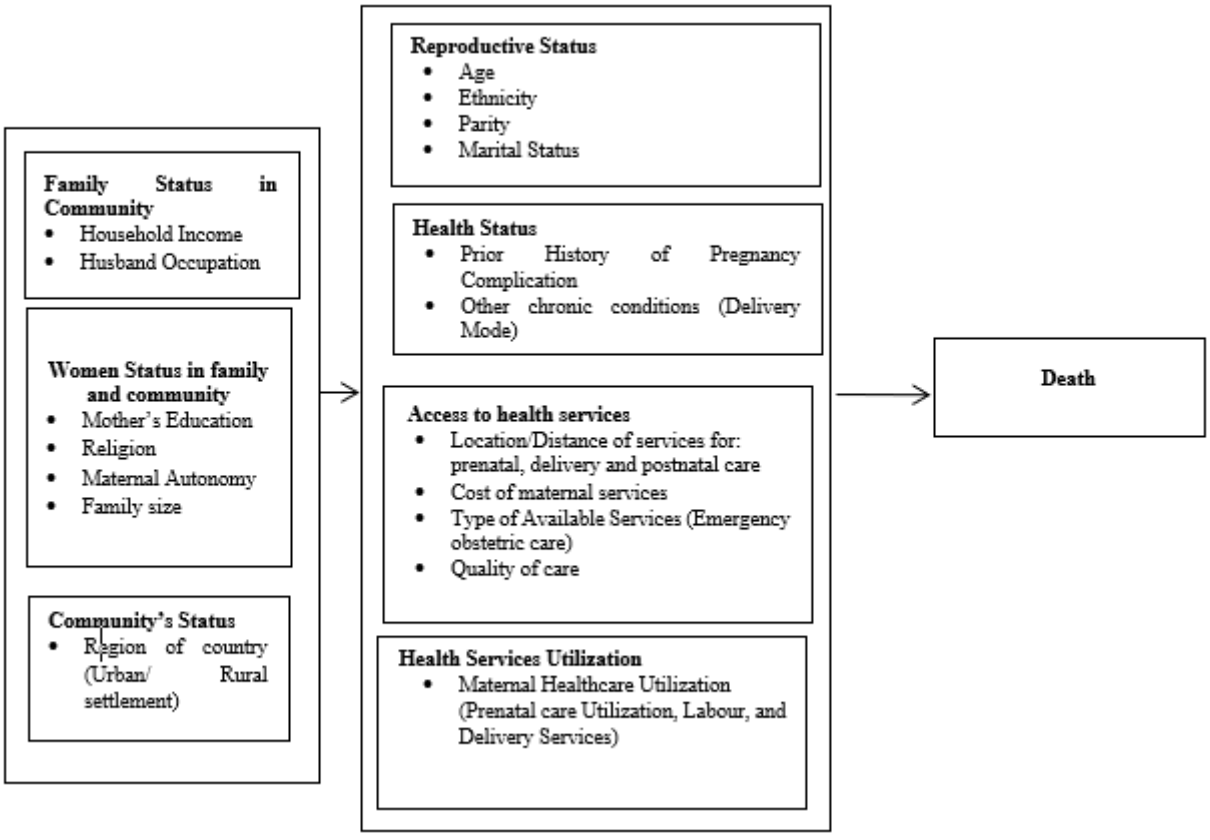

Figure 1: Modified Conceptual Framework based on Individual, Family, Community, and Medical Determinants of Maternal Mortality/Disability.

There are regional, state, and health facilities records of high maternal death in Edo State. Research from 2008 to 2020 depicts a state with a high maternal mortality ratio of 395 to 3877 per 100, 000 deliveries (Abe & Omo-Aghoja, 2008; Ande et al., 2012; Okonofua et al., 2018, Ntiomo et al., 2018; Aikpitanyi et al., 2019 John-Abebe & Osirike, 2020). Edo State also records high fertility rates and low family planning which results in high maternal mortality/morbidity (NPC & ICF, 2019). The lack of records to depict where these maternal deaths occur and the factors that drive the high number of deaths are crucial for effective interventions. In a bid to achieve sustainable developmental goals for 2030, the Nigerian government needs to employ new strategies in gathering information on maternal death, and implement holistic individual, household, and community-level models to address these challenges across geographic areas with high mortality data, which this research hopes to examine.

Essentially studying the spatial variation of maternal death especially in rural communities is to identify communities where healthcare systems are plagued with the lack of personnel and overstretched facilities with high levels of poverty. For effective management of maternal healthcare needs in a state with scarce resources, the government needs to prioritize and target communities and challenges affecting maternal healthcare needs. In essence, this research seeks to investigate the socio-demographic, spatial-temporal variations, and healthcare determinants that influence maternal death in Edo South, Nigeria.

The determinants were synchronized after the determinants from McCarthy and Maine's Conceptual Framework (1992), and Andersen behavioural model (2005) for analysing maternal mortality and morbidity (Figure 1). These models are helpful in their comprehensiveness and specificity.

Materials and Methods

Study Setting and Research Design

Edo South Senatorial District is located between latitude 5º 44'N and 6º 87'N and Longitude 5º 00' E and 6º 43'E of the Equator. Seven (7) Local Government Areas make up the district: Oredo, Ikpoba-okha, Egor, Ovia North-East, Ovia South-West, Orhionmwon, and Uhunmwode which form the research area (Figure 2).

Within the Edo South Senatorial District, the community-based survey design was applied to investigate the maternal mortality determinants. Using systematic sampling techniques, 1,546 female respondents within the ages of 15 to 49 were selected in the senatorial district. The sampling area comprises (29) areas/wards (urban and rural communities) within the district: *Egor LGA* (Uselu, Ugbowo, Evbuotubu, Egor); *Ikpoba-Okha LGA* (Idogbo, Gorretti, Ologbo, Obanyantor); *Oredo LGA* (Ogbe quarters, Oredo urban (New Benin), Urhegin/Okua and Ekae); *Orhionmwon LGA* (Abiokunla1(Abudu), Urhonigbe, Ugu and Igbanke west); *Ovia North East LGA* (Okada, Ekiadolor, Utoka and Iwu); *Ovia South West LGA* (Iguobazuwa, Usen, Udo and Siluko); *Uhunmwonde LGA* (Ehor, Umagbae South, Ohuan, and Orhua). Female respondents were asked to report maternal deaths and contributory factors of maternal death in their household and amongst their sisters.

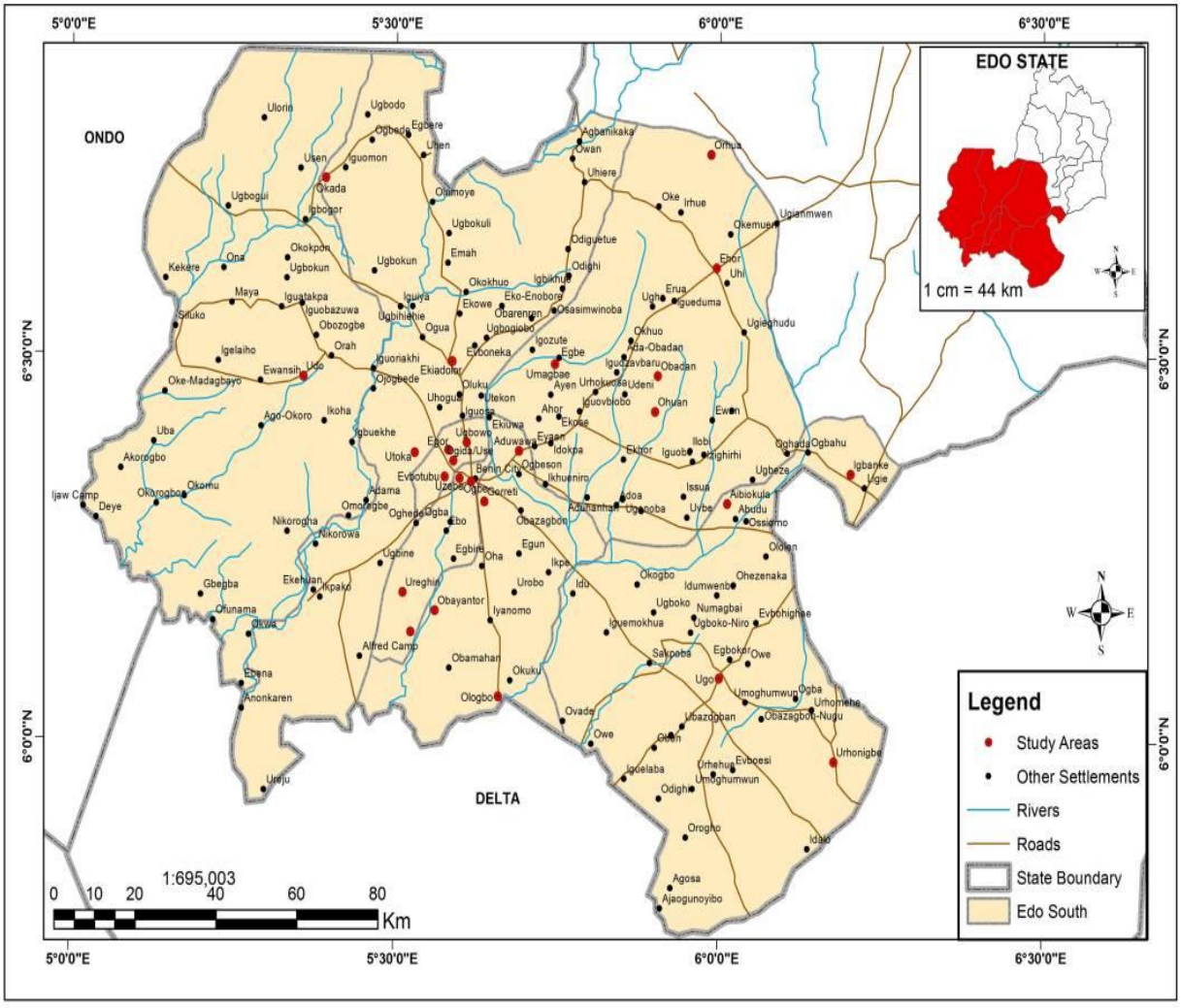

Figure 2: Selected Communities in Edo South Senatorial District inset Edo State

Data Collection

A structured household questionnaire was used in the collection of quantitative data involving 1546 adult women of reproductive age (15–49 years). Respondent's consent was sought at a household level before questionnaires were administered. This is to gather the necessary information on maternal death and to examine the determinants comprising (individual, family, community, and medical) of living or dead women (sisters) with one or more birth experiences. Applying the indirect sisterhood method, respondents also reported on dead siblings within the reproductive ages (born of the same mother) who died during pregnancy, delivery, or post-partum periods. Living siblings provided information on dead sisters on factors affecting maternal mortality. Household coordinates were collected using a GPS handheld device. ArcGIS was used to produce maps of the study area.

Measures

The data involves the maternal death records from 2007 to 2017. Maternal death was coded as a binary variable. For a living woman, the code is 0 while the dead woman is coded as 1. The explanatory variables are socioeconomic, demographic, reproductive, and health-related variables. The determinants include region, age, education, marital status, religion, income, husband occupation, ethnicity, maternal autonomy, family size, number of births, prior history of complication, distance to the health facility, mode of last child delivery, cost of services, place of maternal health utilisation, availability emergency obstetric services, and quality of health services. The study applied the multinomial/binary logistic regression to test the important variables influencing maternal death.

Data Analysis

Multivariate analyses examine the effect of selected variables influencing the incidence of maternal death (social economic, demographic, reproductive, maternal status in family and community and access/utilisation of health services) which is a reflection of (individual, family, medical, and community) factors among reproductive women. Two models of regression techniques were used in the analysis to depict spatial variation among selected independent variables on maternal death. The Multinomial logistic regression (Model 1) provides a means of investigating the independent variables on maternal mortality outcome.

To ascertain the impact of explanatory variables on maternal mortality, multinomial/binary regression was applied using odds ratio. Using STATA version 13, the 1546 responses from the questionnaires were coded accordingly within the application's data editor and were entered into the statistical technique algorithm. The logistic regression model is expressed as:

$$Log\ \rho\ [1-\rho] = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta kXn + \mu\ 1$$

In this analysis, geographically weighted regression (GWR) (Model 2) was used to spatially explore the relationships between maternal mortality and the selected predictors. GWR assumes local non-stationarity in relationships i.e., these relationships change from location to location. The model's equation for GWR as presented by (Fotheringham et al., (2002) is:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

Where:

(u_i, v_i) is defined as the geographic location represented by the coordinates of the ith point in the study area;

$\beta_k(u_i, v_i)$ is the continuous surface of parameter values, and measurements of such surface are allowed and observed at certain points to depict the spatial variability of the surface.

y_i represents the ith term of the dependent variable (maternal mortality outcome) relative to the independent variables x_{ik},

while ε_i is the error term.

GWR shows the relationship existing between maternal deaths, individuals, households, communities, and medical factors based on local government by local government comparison. Maternal mortality was aggregated into two areas (urban and rural). The local coefficient depicts the level at which independent variables strongly predict maternal mortality. ArcGIS 10.4 was used for the computation of the model. The dependent variable was standardized to conform to the model's data requirement. Before Model 2 was computed, a validation procedure using Factor Analysis was conducted on the data to ascertain the fitness and appropriateness of the data on the local model. Model 2 checks for multi-collinearity among the eighteen (18) predictors which global model could not detect in Model 1.

Results and Discussion

The logistic regression (Model 1) was applied to investigate the effect of the number of predictors on maternal deaths in selected communities. The odds ratios examine the determinants of maternal mortality at a 0.05 level of confidence (Table 1a,b,c). The probability statistics (Prob > chi2) of the model returned a general P-value of 0.0020 which makes the model statistically significant.

The results of Model 1 show that respondent's education is a predictor of maternal mortality. All the sub-variables returned significant P-values of 0.004, 0.002, and 0.001 (primary education; secondary education, and post-secondary education) respectively. This means that when women become educated the odd ratio of maternal death during childbirth is 0.27 for primary education and secondary education 0.26 and finally for post-secondary education is 0.22. By implication, the odd ratio of maternal death during childbirth seems to drop as educational attainment increases. In other words, there is a lesser chance of the most educated women dying during childbirth compared to women with lesser education. This concurs with Meh et. al. (2019) and Woko et. al. (2021) position that women who are educated are protected against maternal death, unlike women with no education.

The number of previous births predictor returned significant P-values for 1-2 (0.041) and 3-4 (0.004). This means that the odd ratio of maternal death during childbirth increases by 0.61 for women who had previously had 1-2 births. For women who had previously had 3-4 births, it increases by 0.46. In other words, the chances of maternal mortality during childbirth reduce with the increasing number of historical births. This is consistent with other studies in India and Nigeria (Hamal et al., 2020; Woko et al., 2021) that depict the impact of parity (number of births) on maternal death. Societies with high birth rates experience high maternal mortality but women who are educated and patronise healthcare facilities reduce the risk of mortality.

With a significant P-value of 0.000 for women who have had a history of complication during birth, the result revealed that the odd ratio of maternal death during childbirth increases by 2.08 for women who had a prior history of complication compared with those who have not. Mothers who experience complications during any of the periods of pregnancy, delivery, or after delivery are faced with the likelihood of a maternal death in many parts of the country (Azuh et al., 2017; Ntiomo et al., 2018).

The mode of last delivery was significantly related to maternal mortality. The result shows that this predictor is significant with a corresponding P-value of 0.013 for the caesarean section option. It means that the odd ratio of maternal death during childbirth increases by 2.04 for women who have had a caesarean section in a previous birth than those who had a normal birth. Studies concur with this finding that maternal death increases with mothers who are faced with caesarean section in health facilities especially if they experience any of the three delays or are unbooked patients and did not utilize health care facilities for their ante-natal care services (Ntiomo et al., 2018; Woko et al., 2021).

The predictors associated with maternal death in the district emphasize the importance of social-economic, demographic, reproduction, and medical/health status. The study reveals that first-time mothers are faced with maternal death, which could be due to low patronage of health facilities. Early abortion and the prevalence of HIV/AIDS within the study area have been identified to be some causes of maternal death (Omo-Aghoja et al. 2010; Onakewhor et al., 2011; Ande et al., 2012). The record of high maternal death among less educated women is also argued by some researchers in the country (Ntiomo et al., 2018; Woko et al., 2021) which could lead to poor patronage of health facilities and high mortality among unbooked mothers.

Okonta et. al. (2002) study reveals the effect of socioeconomic status (education) in reducing maternal deaths and suggests women's education in the intervention programmes. The high number of pregnancies increase maternal death outcome; this could be a reflection of complication experienced by women in the study area (Woko et al., 2021, Meh et al., 2019). The state records high fertility which is a factor influencing maternal mortality (NPC and ICF, 2019). High maternal mortality is linked to unbooked patients (less than 15 years) who are first-time mothers.

Table 1a
Logistics Regression with Odd Ratio for Maternal Mortality Determinants

Variables	Odds Ratio	Std. Err	Z	P>|z|
Intercept	0.38	0.53	-0.7	0.486
Region				
Urban (R)				
Rural	0.9	0.18	-0.37	0.714
Age				
15-19 (R)				
20-24	0.76	0.32	-1.66	0.512
25-29	0.99	0.4	-0.02	0.983
30-34	0.97	0.4	-0.08	0.938
35-44	1.08	0.46	0.17	0.864
45-49	0.92	0.45	-0.18	0.855
>49	1.4	0.72	0.66	0.511
Ethnicity				
Bini (R)				
Igbo	1.31	0.39	0.91	0.364
Ika	1.2	0.62	0.35	0.727
Igarra	0.69	0.59	-0.43	0.668
Ibibio	1.33	0.81	0.46	0.647
Idoma	1.92	2.36	0.53	0.596
Tiv	7.69	11.99	1.31	0.19
Efik	0.81	0.95	-0.18	0.859
Ibo	1.62	0.79	0.99	0.32
Igbira	1	-	-	-
Esan	1.23	0.26	1.02	0.307
Estako	0.74	0.24	-0.94	0.348
Hausa	1.03	0.98	0.04	0.972
Ijaw	0.85	0.59	-0.24	0.813
Isoko	0.72	0.61	-0.39	0.696
Itsekiri	2.24	1.53	1.18	0.238
Kwale	3.48	4.43	0.98	0.329
Urhobo	0.44	0.2	-1.8	0.071
Ora	1	-	-	-
Owan	0.5	0.53	-0.65	0.518
Yoruba	0.74	0.39	-0.58	0.564

At a P-value of 0.05 level of significance (Bold).
*Reference category = R

Table 1b
Logistics Regression with Odd Ratio for Maternal Mortality Determinants

Variables	Odds Ratio	Std. Err	Z	P>|z|
Intercept	0.38	0.53	-0.7	0.486
Marital Status				
Single (R)				
Married	0.7	0.19	-1.27	0.205
Separated	0.65	0.43	-0.65	0.515
Divorced	1	-	-	-
Widowed	1.39	0.75	0.62	0.538
Education				
No education (R)				
Primary education	0.27	0.12	-2.86	0.004
Secondary education	0.26	0.11	-3.16	0.002
Post-secondary education	0.22	0.09	-3.4	0.001
Religion				
Christian (R)				
Muslim	1.2	0.61	0.36	0.72
Traditional worshipper	0.63	0.38	-0.76	0.446
Husband Occupation				
Civil/Public Servant (R)				
Entrepreneur	1.08	0.21	0.4	0.68
Trader	1.41	0.31	1.56	0.119
Farmer	1.34	0.38	1.02	0.764
Family Size				
None (R)				
01-Mar	1.37	0.53	0.81	0.42
04-Jun	1.19	0.45	0.45	0.654
07-Sep	0.6	0.3	-1.01	0.315
>10	1.26	0.82	0.35	0.723
Number of Previous Births				
0 (R)				
01-Feb	0.61	0.15	-2.04	0.041
03-Apr	0.46	0.12	-2.88	0.004
05-Jun	0.7	0.29	-0.83	0.408
07-Aug	0.64	0.42	-0.68	0.495
>9	0.63	0.6	-0.51	0.61

At a P-value of 0.05 level of significance (Bold).
*Reference category = R

Table 1c
Logistics Regression with Odd Ratio for Maternal Mortality Determinants

Variables	Odds Ratio	Std. Err	Z	P>|z|
Intercept	0.38	0.53	-0.7	0.486
Prior History of Complication No (R)				
Yes	2.08	0.43	3.54	0
Distance of Health Care Location From <1km (R)				
1-2km	1.34	0.29	1.35	0.176
>2km	0.95	0.33	-0.14	0.889
Mode of Last Delivery				
Normal (R)				
Caesarean section	2.04	0.59	2.48	0.013
Cost of Maternal Care Service Free (R)				
1,000-20,000	0.96	0.38	-0.1	0.917
21,000-40,000	0.98	0.41	-0.06	0.956
41,000-60,000	0.89	0.39	-0.26	0.792
>60,000	0.76	0.37	-0.56	0.574
Emergency Obstetric Service No (R)				
Yes	1.28	0.24	1.29	0.196
Hospital Care Utilization Church (R)				
Traditional home	2.12	2.51	0.64	0.524
Primary health care	0.9	1.05	-0.09	0.931
Government/private hospital	1.34	1.55	0.25	0.801
Quality of Health Service Excellent (R)				
very good	1.24	0.38	0.69	0.49
Good	1.32	0.39	0.94	0.346
Bad	1.23	0.49	0.52	0.604
very bad	2.19	1.82	0.95	0.342
Women Free Right to Seek Health Care No (R)				
Yes	1.01	0.26	0.04	0.966

At a P-value of 0.05 level of significance (Bold).
*Reference category = R

Factor Analysis and Geographical Weighted Regression for Maternal Mortality

Factor analysis was computed using the independent variables in Model 2. The analysis was instructed to retain factors greater than and equal to 1. Six (6) Factor components were retained for this analysis. These explained about 56 percent of the variation in the dataset (Table 2).

The result of the analysis (the retained factor scores) was saved as regression factor scores to be used as independent variables for GWR. The pattern matrix applied the Oblimin rotation method. The principal component extraction method was adopted and absolute values less than 0.4 were suppressed and the coefficient display format was set to sort by size. As shown in Table 3, Factor 1 was termed social economic status and it loads high on predictors such as household monthly income, educational level of respondent, and husband's occupation. Factor 2 refers to the demographic status with predictors such as the number of previous births, age, family size, and marital status. Factor 3 was named reproductive status because it loads high on the mode of last child delivery, cost of maternal care services, and prior history of complication variables. Factor 4 was called access to health services because it loads high on such independent variables as region category and distance of residence from a health facility. Factor 5 was named maternal autonomy about ethnicity and religion since it loads high on religion, ethnicity, and women's healthcare autonomy in the community. Finally, Factor 6 was named the quality of health care with a high load for predictors such as quality of health care rating and health facilities that offer emergency obstetric services.

Local Model using Geographical Weighted Regression

The output of the GWR presented a set to test the best fitness and model's appropriateness in Table 3. The fitness parameters used for the model's comparison show significant variation. For example, -2 log-likelihood, AICc and cross validation (CV) returned smaller values for the GWR model. This is an indicator that the application of the local model is the right choice since it would give a better fit. The R^2 statistic significantly improved from 0.028144 (2.81 percent) to 0.033450 (3.35 percent). This further confirmed that the local model's explaining power is higher. This is because GWR (Model 2) accounted for an additional 0.0053 percent value not explained by the ordinary least square (OLS) model.

The local R^2 spatial smoothing of the GWR model shows that there is a regional disparity in the strength of the relationship in Edo South, Nigeria. Figure 3 shows that the relationship between the independent variables and maternal mortality outcome varies across the Edo South Senatorial District. At the local level, the local R^2 has the lowest value of 0.026 and the highest value of 0.078. This implies that the model explains between 2.6 percent and 7.8 percent with a spatial variation of 5.2 percent. This means that fluctuation (non-stationarity) in the strength of relationship across the area exists. In Figure 3, the colour ramp is a gradient of red to medium yellow and to blue. The areas in red represent those with stronger fitness and blue with weaker fitness, while medium yellow falls in the intermediate. The pattern suggests that respondents in rural communities seem to return stronger R^2 values. For example, the rural areas in Orhionmwon LGA (Ugu and Igbanke) returned strong R^2 values of 0.078 and 0.044 respectively, while urban communities in the same LGA (Urhonigbe and Abudu) returned lower R^2 values of 0.052 and 0.043 respectively.

The GWR model's local R^2 (Figure 3) shows a rich spatial pattern with a higher positive relationship distributed around the core urban center of the region. The red colour indicates a high association while the blue indicates a lower association. The former corresponds with the less urbanized areas of the region while the latter corresponds with the more urbanized parts of the region. This pattern suggests that maternal mortality outcome as influenced by the predictors is higher in the rural region of the study area.

Table 2. Matrix Pattern from Factor Analysis

Variables	Component					
	1	2	3	4	5	6
Social Economic status						
Household Monthly Income	0.76					
Educational Level of Respondent	0.75					
Husband's Occupation	-0.6					
Demographic status						
Number of Previous Births		0.812				
Age of Respondent		0.759				
Family Size		0.745				
Marital Status		0.549				
Reproductive status						
Mode of Last Child Delivery			0.818			
Cost of Maternal Care Services			0.712			
Prior History of Birth Complication			0.692			
Access to health services						
Distance of Healthcare Facility from Residence				0.787		
Region Category				0.761		
Maternal autonomy						
Religion					0.695	
Ethnicity Code					0.591	
Decision to Seek Health Care During and After Delivery?					-0.44	
Quality of healthcare						
Quality of Health Services Rendered by the Facility						0.848
Health Facility Offering Emergency Obstetric Services						-0.481

Note: Variables <0.4 which are regarded here as low factor loadings were not shown

Table 3. Model Fitness Comparison

Fitness parameter	OLS	GWR	Variance
-2 log-likelihood	1248.765337	1240.301180	8.46157
AICc	1264.859026	1262.466913	2.392113
CV	0.132660	0.132486	0.000174
R^2	0.028144	0.033450	0.005306
Adjusted R^2	0.023720	0.025952	0.002232

The result of GWR shows that Factor 1 (social economic status) as a predictor exerts a strong negative influence on maternal mortality outcome in general. This is because all the items of the local coefficient returned negative values (Figure 4A). This kind of negative relationship implies that any increase in household monthly income, educational level including that of the mother, and a change of husband's occupation to a more lucrative one has a high likelihood of reducing maternal mortality outcome. In other words, improvement in social economic status of the people in the region may lead to maternal mortality reduction. Specifically, the inverse relationship that social economic status exhibits on maternal death is stronger in the Uhunmwonde LGA. A high influence is also found and the Southern margin of Ovia North-East and Ikpoba-Okha LGA. Social economic status seems to have a weaker influence on the greater part of Orhionmwon and Ovia South-West LGAs. This means that social economic attribute is a weak predictor of maternal mortality in these areas.

Factor 2 (demographic status) returned a stronger negative relationship (Figure 4B). This means that as the concerned predictors that compose the demographic status increase the outcome of maternal death decreases. The variables of demographic status that influence maternal mortality are number of previous births, age of respondent, family size, and marital status. However, the local coefficient for Factor 2 (Figure 4B) revealed that the relationship points to negative and positive directions. It shows that 1445 respondents returned negative local coefficient values and these are found in mostly urban communities situated in Ikpoba-Okha, Oredo, Egor, Ovia North-East, Ovia South-West, and part of Uhunmwonde LGAs. It means that in these communities, variation in demographic attributes may lead to a decrease in maternal mortality. For the other respondents (i.e., the remaining 101) the local coefficient values are positively related to maternal mortality outcome. The implication of this is that in these communities, the variation in demographic attributes (number of previous births, age, family size, and marital status) may increase maternal death. This pattern is found in the Northeast part of Uhunmwonde and the Southeast part of Orhionmwon.

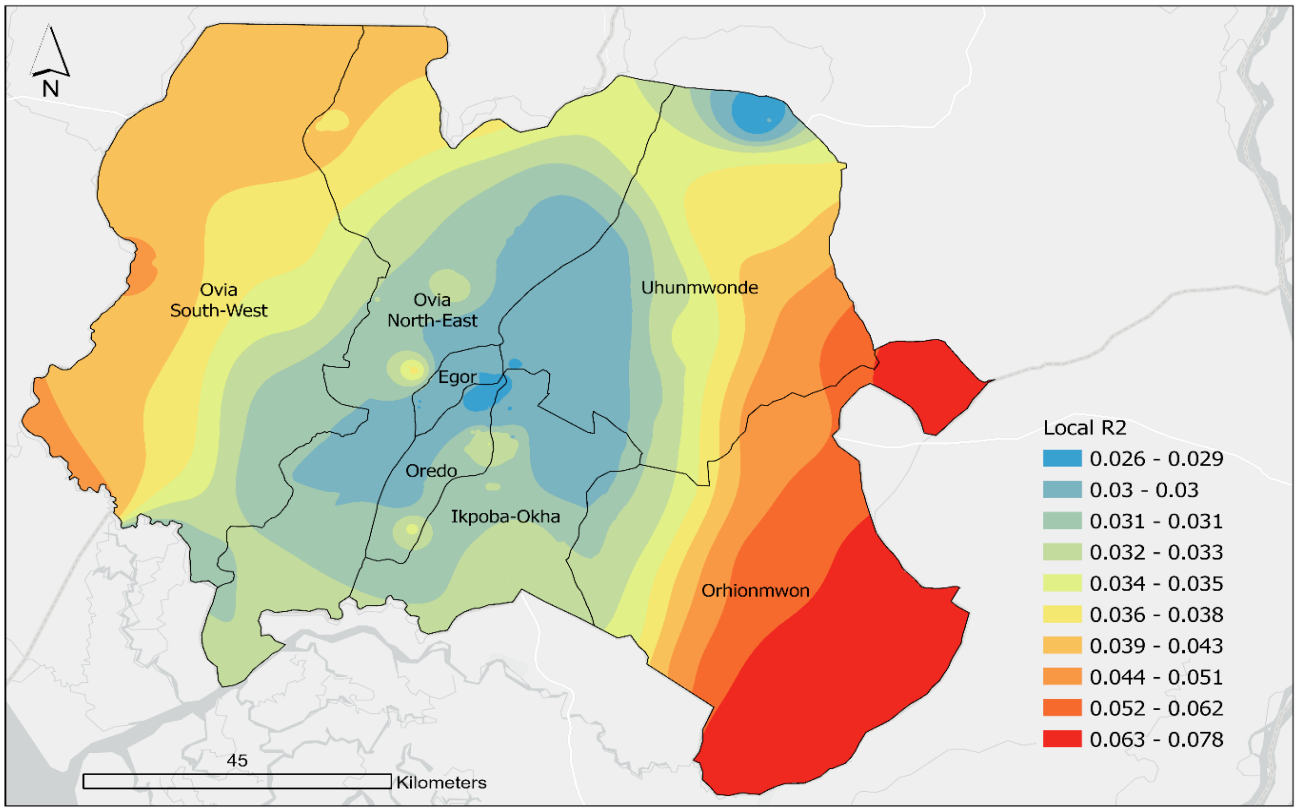

Figure 3: Local R^2 Smoothing for GWR on Maternal Mortality Outcome

As shown in Figure 4B, the influence of Factor 2 which is the score of demographic status is stronger in Orhionmwon and Uhunmwonde LGAs since a greater proportion of the area returned a high coefficient value. In Uhunmwonde LGA, only Obayantor and Uhunmwonde communities among other sampled communities returned stronger local coefficient values. Other communities where demographic attributes strongly explain maternal mortality are Orhionmwon, Igbanke , and Ohuan town in Orhionmwon LGA.

Factor 3 represents the reproductive health dimension (composed of such variables as the mode of last child delivery, cost of maternal care services, and prior history of complication). The GWR result (Figure 4C) for this predictor variable shows that generally, there is a strong positive relationship between the predictors of reproductive health and maternal mortality outcome. Figure 4C shows that the Southern and Southeast parts of the region returned stronger association. From the local perspective, the model shows that concerning this factor the direction of the relationship is essentially positive. The areas with the strongest influence are found in the communities of Orhionmwon, Ikpoba-Okha, Ovia North-East, Southern part of Oredo. This implies that any changes in the reproductive health of the people living in these areas may increase maternal mortality. Other areas have a low positive influence regarding the level at which reproductive health explains maternal mortality. These communities are found in the Northeast part of Uhunmwonde, Ovia South-West of the region.

Factor 4 which represents access to healthcare services generally returned a strong positive GWR coefficient value. Figure 4D shows that there are some communities where weak inverse relationships occurred e.g. Igbanke, Umagbae, Obayantor, Ehor, Orhua, Okada, and Abudu. These communities returned low negative association (as seen in Figure 4D) which indicates that Factor 4 is not a strong predictor of maternal mortality outcome in these areas. Specifically, Figure 4D shows that most of the communities returned strong positive coefficients. Some of these communities are Ekae, Ologbo, Ogida, Oredo, New Benin, Udo, Umagbae, Igbuobazuwa, Ugbowo, Ekiadolor etc. Caution needs to be taken when interpreting this result because of the character of predictors that were extracted as the factor 4 score. It would be misleading to interpret the coefficient as indicative that as access to healthcare services increases maternal mortality rate. The best practice is to carry out the interpretation based on individual variables that make up the factor.

As shown in Factor 5, the variables with high factor loadings are region category (urban or rural), and distance of healthcare facility from residence. Therefore, changes from urban to rural may increase maternal mortality since healthcare facilities are more in the urban regions; hence, access is higher compared to rural regions. Concerning the distance of the healthcare facility from the respondent residence, the result implies that as the distance of residence increases from the healthcare facility, maternal mortality also increases.

Factor 5 represents variables that returned high loadings on maternal autonomy regarding ethnicity and religion. These are religion, ethnicity, and giving women the right to seek healthcare during and after delivery. The majority of the communities generally returned negative relationships and these communities are found within and around the urbanized areas of the region (Figure 4E). In these areas (Oredo, Egor, Ikpoba-Okha, and Ovia North-East LGAs) the influence of religion and ethnicity is relatively lesser because of urbanization which creates a mixed religious and ethnic system. The implication of these is that as maternal autonomy increases in these locations, maternal mortality reduces. This makes sense because maternal autonomy is likely to be higher in urban areas. On the other hand, the rural parts of the Orhionmwon, Ovia North-East, Ovia South-West, and Uhunmwonde seem to return stronger and more positive relationships. The most appropriate interpretation of this is that maternal autonomy is lower here because of the influence of the rural settings which promote strong ethnic and religious characteristics. By implication, as the influence of religious and ethnic characteristics increases in these locations, maternal death increases.

The quality of healthcare services and facilities that operate emergency obstetric services is represented as Factor 6. These variables load high and hence were classified as quality of health care factors. Figure 4F shows that this variable returned a negative relationship with maternal death across all locations. The more urbanized communities have stronger associations and these are found in Egor, Oredo, Ikpoba-Okha, and part of Ovia North-East and Uhunmwonde LGAs. These are communities that form the greater part of Benin City. This means that maternal mortality reduces as the quality of healthcare increases.

Spatially, the application of GWR in the study shows that some factors exert negative results on maternal mortality, especially in rural areas depicting the increase in mortality on some predictors. Studies across the world have shown the relevance of this model in reducing maternal mortality (Fadilah et al., 2019; Dewi et al., 2019; Purhadi et al., 2021). The improvement in the maternal mortality predictors would assist in maternal mortality reduction and indicate the predictors/areas where governments, agencies, and organisations need to intervene to reduce maternal deaths.

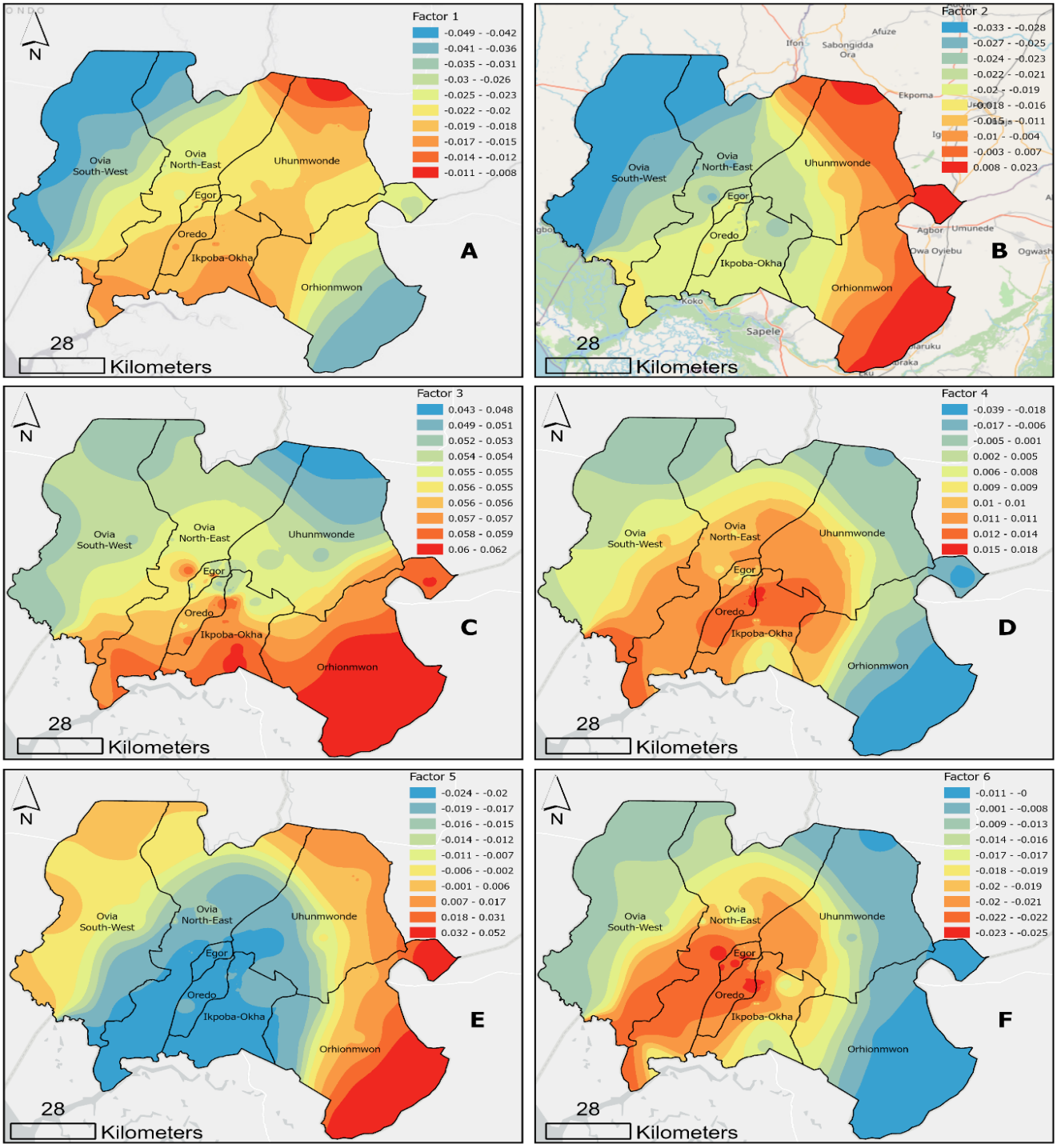

Figure 4: Local Coefficient for GWR for Factors 1 to Factor 6

Conclusion

From this analysis, four (4) significant determinants (education, parity, mode of last delivery, and prior history of complication) affect maternal mortality and they differ by communities within the district. Better management and improving the educational status of reproductive women could affect the best maternal outcome and reduce pregnancy complications especially as the state records high fertility. This calls for continuous campaigns by state policymakers for utilization and access to professional obstetric services for first-time mothers and subsequent deliveries. Six factors explained the variation in the dataset. The pattern suggests that maternal mortality outcomes may be higher in the rural region of the study area. The Geographic Weighted Regression (GWR**)** model illustrates a strong regional disparity in the study area. The identified variables plaguing pregnant women in the senatorial district need to be urgently addressed. This will curb the high ratio of maternal mortality in the district particularly in rural areas.

This study recommends the overall improvement in the social economic, reproductive, and healthcare status of women within the reproductive ages in the district. Governments and organisations should apply the grassroots approach in their intervention programs and policies according to the specific determinant influencing maternal death in each community across the state and country in order to ensure optimum maternal outcome.

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