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The Social Geography of Women's Attitudes toward Wife-beating in Ethiopia: A Contribution Towards Proper Application of Spatial Statistics

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Abstract

Spatial statistical measures have been applied to Ethiopia's Demographic and Health Survey data (EDHS), mostly at the national level. However, there is concern that most applications violate basic principles of statistics regarding autocorrelation, or are not cognizant of the first law of geography which states that all things are related but near things are more related. This study investigates local variations in attitudes toward wife-beating in Ethiopia with education as the main correlate. It does so by using a spatial measure known as the geographically weighted regression (GWR) which is more appropriate in conditions of geographic non-stationarity than the ordinary least squares regression (OLS). Equally importantly, it examines the appropriateness of existing OLS-based spatial studies of EDHS data. We found that most studies inappropriately applied OLS despite findings of spatially autocorrelated data. The GWR model showed an association between acceptance of wife-beating and educational status. It also generated a list of twelve sampling clusters where most women respondents stated that wife-beating was acceptable while admitting to having had no formal education, and where local R^2s exceeded 0.5 in GWR modeling involving 72 nearest neighbors per sampling cluster. An education-focused bi-variate rather than multi-variate GWR avoided issues of multicollinearity while keeping the model simple and its results actionable. Although the majority of the twelve sampling clusters are in Harari Wereda and Kilil, which got their name from members of the Harari ethnic group that are predominantly Muslim, it is difficult to pinpoint which factor or set of factors can be cited as causally associated with characteristics that placed them on the list. The study makes methodological contributions to spatial studies of sociodemographic characteristics of populations, especially those in developing countries such as Ethiopia where local factors show significant geographic variations. It also adds to the literature on applied geographically weighted regression.

Keywords: domestic violence, Ethiopia, geographically weighted regression, wife-beating

1. Introduction

1.1 Statement of the Problem: Issues Related to the Application of Global Ordinary Least Squares Regression (OLS) to Spatial Data

Sociodemographic data are often collected at geographic scales ranging from small neighborhoods to a national level. In this study, the spatial levels range from the finest geographic detail – sampling cluster – to Wereda (district), Kilil (region or province), and the nation. The study focuses on statistical modeling in which linear regression is used to simulate real-world relationships between a dependent variable and a set of one or more independent variable(s). There are quantifiable gaps between model predictions and observed values (Charlton & Fotheringham, 2009). Another name for the gap is residual. A properly constructed linear model would have residuals that are a) normally distributed with no autocorrelation (Chen, 2016), and b) have constant variance (homoscedasticity) when plotted against independent variables (x) or the predicted variable ($\hat{y}$) (Yang & Chen, 2019). These two assumptions are often violated in the case of spatial data due to Waldo Tobler's classic observation and the first law of geography: that "everything is related to everything else, but near things are more related than distant things" (quoted in Charlton & Fotheringham, 2009). This makes results from ordinary least squares (OLS) regression biased and unreliable. When it comes to spatial data, the violation can be verified further using Moran's I statistic (Ord & Gettis, 2002).

As will be discussed in the below paragraphs, a number of studies featuring the geographical analysis of Ethiopia's demographic and health survey data (EDHS), improperly applied OLS despite findings of autocorrelation and without testing for constant variance (homoscedasticity) or uniform distribution of residuals. The few studies that found spatial autocorrelation and refrained from applying OLS, or tested for the randomness of residuals before applying the method include the 2018 analysis of children ever born with spatially clustered high and low births, and the comparison of Amhara and Tigray's Kilil's economies which showed clustering of poverty and wealth in both regions (Aynalem, 2018, 2019). A spatial study of perinatal mortality and its determinants (Yadeta, Mengistu, Gobena & Regassa, 2020), also found clustering and refrained from applying OLS regression. Ejigu et al.'s (2023) modern contraceptive use study and Bogale, Gelaye, Degefie & Gelaw's (2017) patterns of childhood diarrhea also limited their focus to spatial interpolation and rightly refrained from applying OLS regression.

1.2 Existing Spatial Analyses of the EDHS Data

Most published works featuring spatial analyses of EDHS data suffer from one or more flaws, including 1) application of bi- or multi-variate global (countrywide) OLS regression to a spatially autocorrelated response variable (y) (Seid, Melese & Alemu, 2021, Defar, Okwaraji, Tigabu, Persson, & Alemu, 2016; Agegnehu, & Alem, 2021), 2) lack of testing for multicollinearity of the chosen independent variables (x), 3) combining the use of spatial and non-spatial statistical methods (Seid, Melese & Alemu, 2021), and 4) publishing contradictory results from different spatial statistical applications, namely, ArcMap (or ArcGIS Pro) and SatScan, in the same paper (Seid, Melese & Alemu, 2021). One such example is the analysis of domestic violence in Ethiopia with the authors highlighting its spatial clustering and yet proceeding to conduct global OLS regression (Seid, Melese & Alemu, 2021). A global OLS regression was chosen for the analysis of places of childbirth data (Awol & Jemal, 2023) and BCG vaccination among children 0-35 months (Agegnehu, & Alem, 2021) despite findings of spatially clustered service delivery. Linear regression was applied to places of birth data (Gudayu, 2022) despite findings of spatially clustered home births. An analysis by Tusa, Weldesenbet & Kebede (2016) found high incidences of underweight children to be spatially clustered, as did the study of common childhood illnesses and service utilization (Defar, Okwaraji, Tigabu, Persson, & Alemu, 2016). Determinants of home births were the subject of another study that found significant clustering but relied on OLS for further analysis (Gudayu, 2022). A global OLS regression analysis of drinking water sources was conducted despite the finding that unimproved water sources were spatially clustered (Bogale, 2020). Childhood wasting in Ethiopia was examined in another global OLS regression that found spatial clustering of wasting in northern, eastern, northeastern, and western parts of the country (Kendalem, 2023). Multi-level regression analysis of household iodized salt utilization (Yeshaw, Alem, Tesema., Teshale, Liyew &Tesema, 2020), and of maternal antenatal care (ANC) (Zemenu & Temesgen, 2020) were conducted despite findings of spatial clustering of the chosen variables. Alemayehu, Agimas, Shewaye, Derseh, & Aragaw (2023) found spatial autocorrelation of households that had limited access to improved drinking water services but went on to conduct a global OLS regression. All of these spatial statistical studies have one thing in common: the application of global least-squared regression to spatially autocorrelated data. Exceptions may be the analyses of under-nutrition among children under five years old by Muche, Melaku, Amsalu, & Adane (2021), and Belay, Adane, Ferede & Lakew's (2022) study of anemia among women of reproductive age. The two studies applied the more appropriate statistic – the Geographically Weighted Regression (GWR). However, their conclusions were centered around OLS (not GWR) and neither study adequately articulated the difference between the two.

1.3 Review of Wife-beating Studies in Other Developing Countries

Studies of intimate partner violence or IPV, often sought to gauge attitudes toward wife-beating among men and women. A study of husbands' attitudes in India (Ying & Koustuv, 2009) found the joint autonomy of wives in decision-making and the ability to manage their earnings, as being protective of women's well-being. In Zimbabwe, the majority (53%) of women, said "yes" to a question on the acceptability of wife-beating in at least one of the five scenarios commonly asked about in global demographic and health surveys – arguing with a husband, leaving the house without telling him, neglecting the children, burning the food, or refusing to have sex (Hindin, 2003). This study only considered the first of the five scenarios which also earned a majority "yes" response in the Afar Kilil of Ethiopia (51.6%). The national average for Ethiopia was lower at 36.4% (Table 1). A study in Bangladesh used what it called "the Inventory of Beliefs about Wife Beating (IBWB)" to gauge the attitudes of women towards wife-beating (Sayem, Begum & Moneesha, 2012). Similar studies have been conducted in Uganda (Speizer, 2010), Palestinian refugee camps in Jordan (Khawaja, 2008), in Turkey (Hacer & Gonenc, 2020), Egypt (Nafissatou, Jacquelyn & Stan, 2006), Nigeria (Sunmola, Mayungbo, Ashefor & Morakinyo, 2020), Ghana (Osei-Tutu & Ampadu, 2017), Cambodia (Yount, & Carrera, 2006), Jordan (Al-Nsour, Khawaja & Al-Kayyali, 2009)., 2009), 39 low- and middle-income countries (Tran, Nguyen & Fisher, 2016), all across Asia (Rani & Bonu, 2009), South Asia (Koustuv, Ming, & Mervyn, 2012), and seven Sub-Saharan African countries including Ethiopia (Manju & Nafissatou 2004). Surprisingly, in many of these studies, wife-beating had greater acceptance among women than among men, and the most commonly observed determinants of women's attitudes toward wife-beating were low education, low socioeconomic status, the age of respondents, and rural residence.

1.4 Implications of Wife-beating for Women's Health

This study's interest in wife-beating relates partly to its direct and indirect consequences for women's health and well-being, including mental health (Roberts, Williams, Lawrence & Raphael, 1999), overall health (Garcia-Moreno, Jansen, Ellsberg, Heise & Watts, 2006) and behavioral health (Dutton, M. A., Haywood, Y., & El-Bayoumi, G., 1997). The harm is said to extend to children's health, developmental stages, and overall well-being which are affected by direct exposure to or witnessing the violence perpetrated against their mothers (Pynoos, & Eth, 1985). A cross-sectional study of married women in rural Ethiopia (Deyessa et al., 2009) has shown spousal control of women, physical and emotional violence, as well as childhood sexual abuse, as being associated with depression. Another Ethiopian study (Shewangzaw, Dargie, Kasahun, & Moltot, 2022) has COVID-19 in the title but did not show the added effect of the disease in the causal associations it found between partner violence and depressive symptoms, suicidal ideation, and body-image disturbances among women. Women in the Abay Chomen district in western Ethiopia were studied in order to quantify the likely co-occurrences of spousal abuse and pregnancy (Abebe, Admassu, & Tilahun, 2016). It showed the prevalence of spousal violence against women during the most recent pregnancy to be 44.5 % (95 % CI, 32.6, 56.4). At 64.2% (95% CI 60.4, 68.2), the co-occurrence was a lot higher among HIV-positive women as shown by a study in the city of Gonder (Alemie, Yeshita, Zeleke & Mekonnen, 2023). A similar study in Wolayta Zone in southern Ethiopia found a co-occurrence of intimate partner violence and perinatal as well as postpartum lived experiences (Tafesse & Negussie, 2021). An important recent study in eastern Ethiopia found statistically significant linkages between intimate partner violence and low birth weight as well as preterm deliveries (Musa, Chojenta, & Loxton, 2021). A study in Agaro town in southwestern Ethiopia focussed on the spousal violence and mental health nexus with the finding that women experiencing sexual, emotional, and physical abuse also faced higher likelihoods of mental distress (Tadegge, 2008). Regarding the impacts on children, a wide-ranging study in South America has shown positive couple interaction as being linked to better health for children (Heaton, & Forste, 2008). Additionally, a comprehensive review of the literature by Plichta, (1992) has shown non-victims of interpersonal violence as being much less likely than victims to have poor mental and physical health. It also found that witnessing or experiencing violence was associated with stressors of the level of magnitude to trigger post-traumatic stress disorder (PTSD) symptoms in children.

2. Study Objectives

In simplified steps, this study will show the application of a spatial statistic known as the geographically weighted regression (GWR) which corrects for spatial autocorrelation and produces mostly local, but also global, regression coefficients. The use of GWR is scientifically valid for spatial data as these data are often clustered. Moreover, it is more appropriate for Ethiopia's highly diverse geographic and cultural spaces. The chosen topic of analysis is Ethiopian women's attitude toward wife-beating, and whether it is related to their educational status. The response variable (y) is the unweighted percentage of women responding "yes" to a question on the acceptability of wife-beating if she argued with her husband. This would be evaluated against unweighted percentages of women responding "no" to a question on whether they had a formal education (x). The goal is to model mainly local, but also global (countrywide) relationships between the educational status of women respondents and our outcome of interest - their attitudes toward wife-beating. The use of education as a sole independent variable (x) avoids issues of multicollinearity as education is closely linked to a number of other independent (x) variables that are nevertheless good candidates for inclusion, including income, wealth, and rural-urban residence. Moreover, education is the most commonly cited determinant of attitudes toward wife-beating in the diverse international studies cited in the introductory sections.

3. Data Source

Ethiopia's 2016 demographic and health survey data is used. This was the fourth demographic and health data-gathering project directed by the Central Statistical Office (CSA) with external financing including funding from the United States Agency for International Development (USAID) and technical assistance from ICF International (CSA, 2016). Three prior surveys were conducted in 2000, 2005, and 2011 (CSA, 2001, 2006, 2012). All surveys focused on women aged 15-49 and men aged 15-59 in randomly chosen households and in the sampling clusters selected for analysis. For the 2016 survey, a total of 15,683 female respondents and 12,688 male respondents were selected from 16,650 households that lived in 643 sampling clusters. The enumeration areas (EAs) of the 2007 national census formed the sampling frame for the 2016 survey (CSA, 2016).

4. Methodology

The geographically weighted regression methodology (GWR) is applied in an easy-to-follow scheme and as a more appropriate model that can be applied to EDHS data when tests show the presence of spatial autocorrelation. The methodology is most appropriate in highly diverse sociocultural environments such as Ethiopia's as its outputs include local regression equations for any focal point within the regressed space (Fotheringham, Charlton & Brunsdon, 1998). In this study, the focal points would be the 643 sampling clusters in EDHS 2016. The open-source R-programing software is used to create tabular data at the regional or Kilil (the primary administrative divisions in Ethiopia) level and at the sampling cluster level. ArcGIS Pro 3.0 is used to conduct the GWR-based spatial regression.

4.1 Testing for the Presence of Spatial Autocorrelation

First, an exploratory ordinary least squares (OLS) regression is conducted between the women's response variable (y) and the education variable (x). This is then followed by testing its appropriateness for spatial regression through the fulfillment of two conditions: a) uniformly distributed residuals and b) constant variance or homoscedasticity of residuals. This can be tested using one or both of the below-listed methods.

(1) The Quantile-quantile plot (Q-Q plot)

(2) Homoscedasticity test or test of constant variance across the line of identity

4.1.1 Q-Q Plots

Figures 1 and 2 provide results of Q-Q plots for standardized residuals from the OLS regression and from GWR respectively. The systematic oscillation of OLS residual (represented by the dashed red line) above and below the blue dotted trendline is indicative of a non-normal distribution (Figure 1) while the tight fit of the GWR residuals (Figure 2), also represented by the dashed red line, is consistent with patterns produced by normally distributed residuals although there is a hint of long tails at both ends. Based on the Q-Q plots in Figures 1 and 2, it would be improper to apply OLS regression to the data at hand but it is appropriate to fit GWR as there are mimimal systematic curvatures astride the line of best fit.

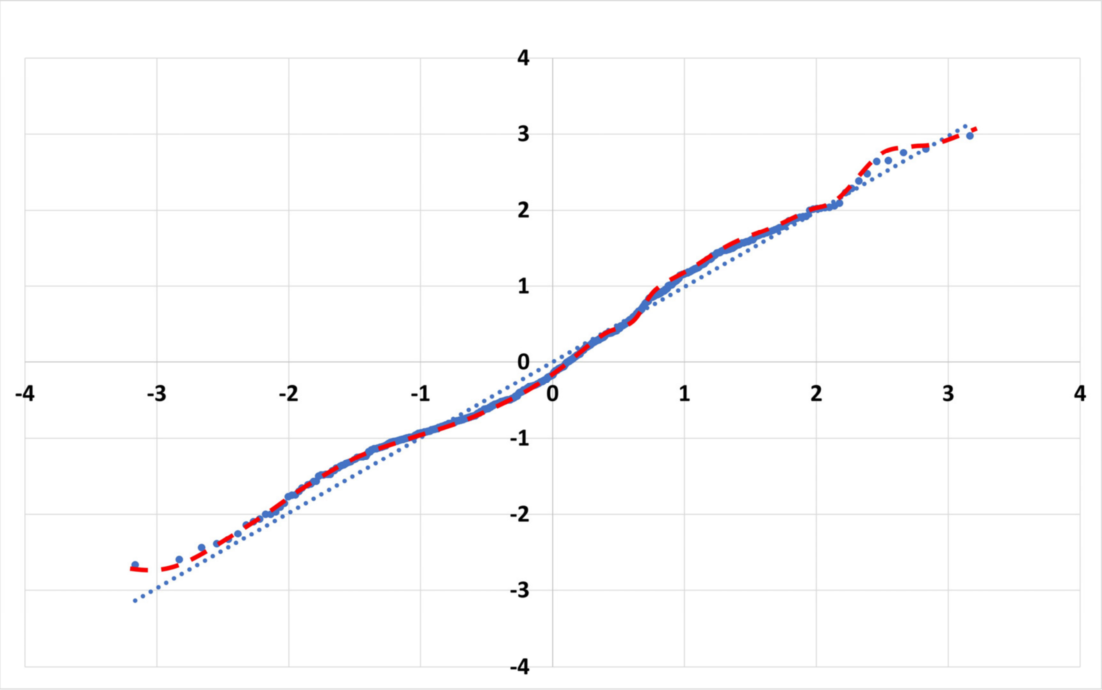


Figure 1. Comparison of Standardized Residuals and Normal Distribution: Ordinary Least Squares (OLS)

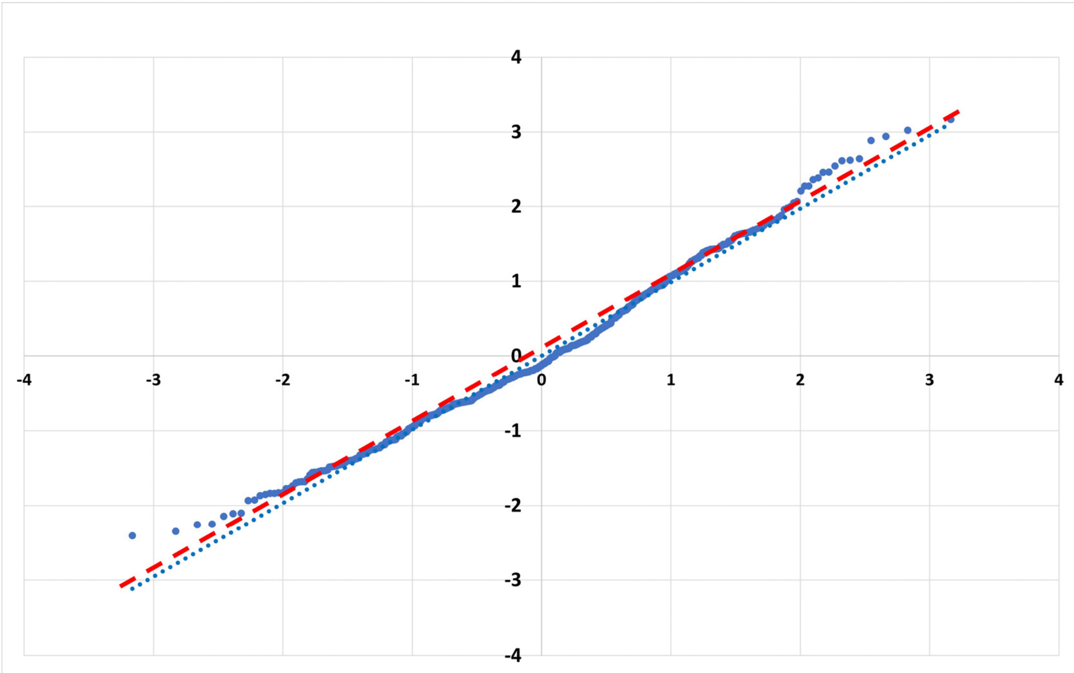


Figure 2. Comparison of Standardized Residuals and Normal Distributions:
Geographically Weighted Regression (GWR)

4.1.2 Homoscedasticity

In an article subtitled "An overlooked critical assumption for linear regression", Yang, Tu, & Chen (2019), argue that homoscedasticity of residuals has a larger effect on the soundness of linear regression results than normality. Homoscedasticity relates to a residual plot where the error term is the same (or has a constant variance) across all values of the predicted response variable (ŷ) or the independent variable(s) (Issa & Nedal, 2011). The plot for the OLS residual in Figure 3 violates this condition as the variance increases with increasing ŷ, whereas the plot for GWR residuals in Figure 4 fulfills the condition with parallel dotted red lines representing average values of the most distant residuals for given values of ŷ. The dotted blue lines represent the sum of all residuals, which is zero.

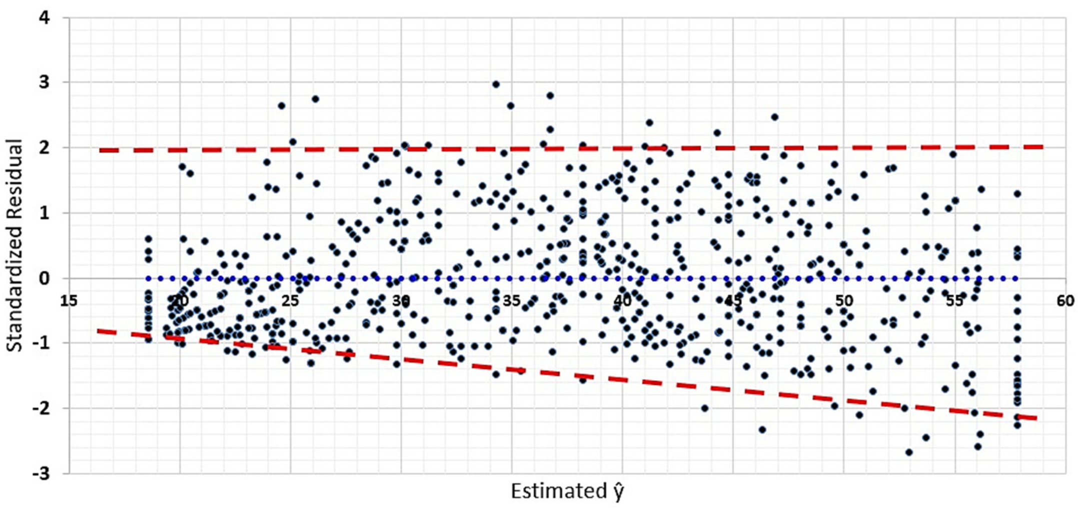


Figure 3. Standardized residuals vs. estimated ŷ: Ordinary Least Squares Residual (OLS)*

* Blue dots represent values of standardized residuals for estimated ŷ, and the blue dotted line represents the trend line or the sum of all residuals which is zero. The dashed red line represents the averages of the most distant residuals for estimated ŷ.

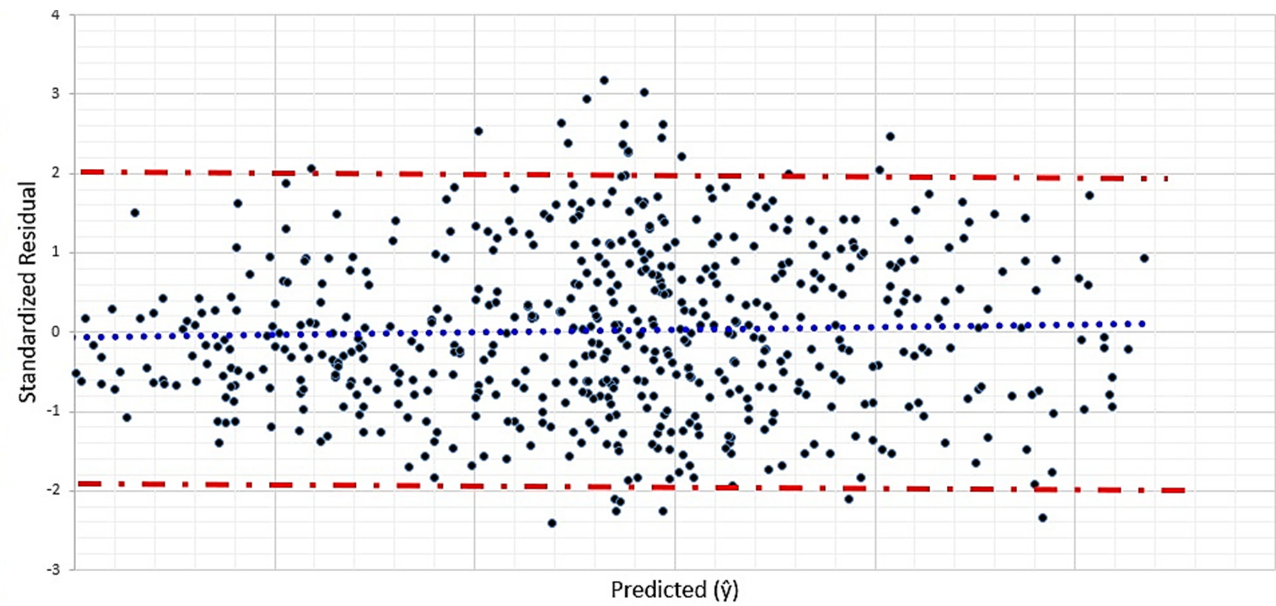


Figure 4. Standardized residuals vs. predicted (y): Geographically Weighted Regression (GWR))*

* Blue dots represent values of standardized residuals for predicted values of ŷ, and the blue dotted line represents the trend line or the sum of all residuals which is zero. The dashed red line represents the averages of the most distant residuals for estimated values of the estimated ŷ.

4.1.3 The Moran's I Index

The Global Moran's I evaluates the presence of spatial autocorrelation on the basis of 1) the location of features, and 2) their values (ESRI, 2023). Results are expressed as dispersed, random, or, clustered (the most common occurrence in spatial data). Global Moran's Index is bounded by -1.0 (dispersed) 0 (random) and 1.0 (clustered). Formulaically, the index is expressed as follows:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \; i \sum_{j=1}^{n} i \, w_{i,j} z_i z_j)}{\sum_{i=1}^{n} \; i \, z_i{}^2} \tag{1}$$

$$S_0 = \sum_{i=1}^{n} \; i \sum_{j=1}^{n} i \, w_{i,j} \tag{2}$$

where: Zi is the deviation of an attribute for feature i from its mean ($X_i - \bar{X}$)

$w_{i,j}$ is the spatial weight between features i and j,

n is equal to the number of features

S_0 is the aggregate of all spatial weights

Formula source: (ESRI, 2023; Jingtao et al, 2021)

Similar to non-spatial statistics, Moran's I produces z-scores and p-values for significance testing by comparing calculated values to the area under the normal curve (ESRI, 2023). Figure 5 repeats the findings of the previous two tests by showing the inappropriateness of OLS as a spatial regression measure for the evaluation of women's attitude toward wife-beating (the y-variable) as it is spatially autocorrelated (Moran's I = 0.23; $p<0.001$). The output shows a less than 1% likelihood that this clustered pattern could result from random chance (Figure 5). On the other hand, given the z-score of almost zero (Moran's I = -0.02), for the GWR residuals, the pattern does not appear to be significantly different than random (Figure 6) further confirming that the GWR approach is sound as it improves the model fit by correcting for spatial autocorrelation and by normalizing the residuals.

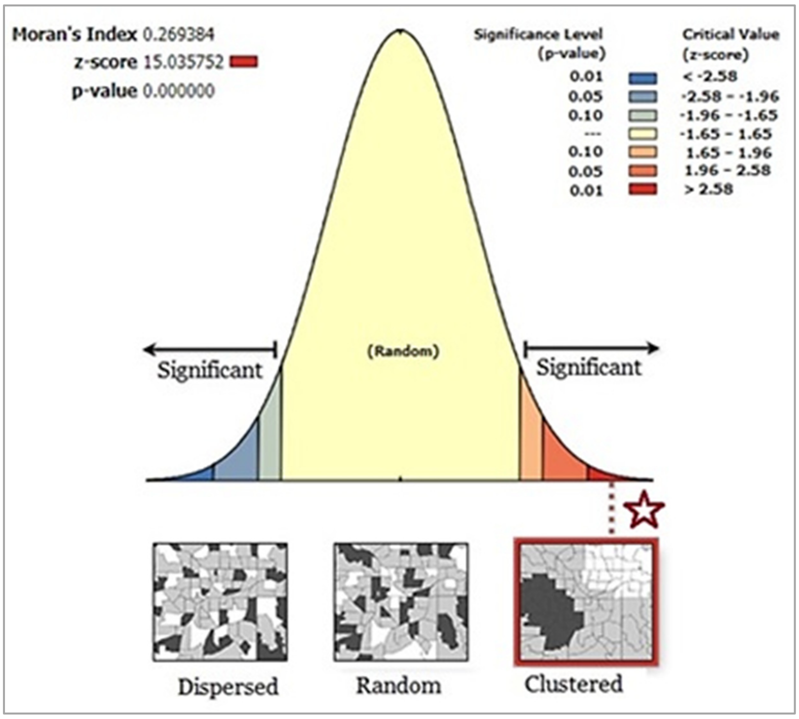


Figure 5. Moran's I Index and Residual Plots: Ordinary Least Squares (OLS)

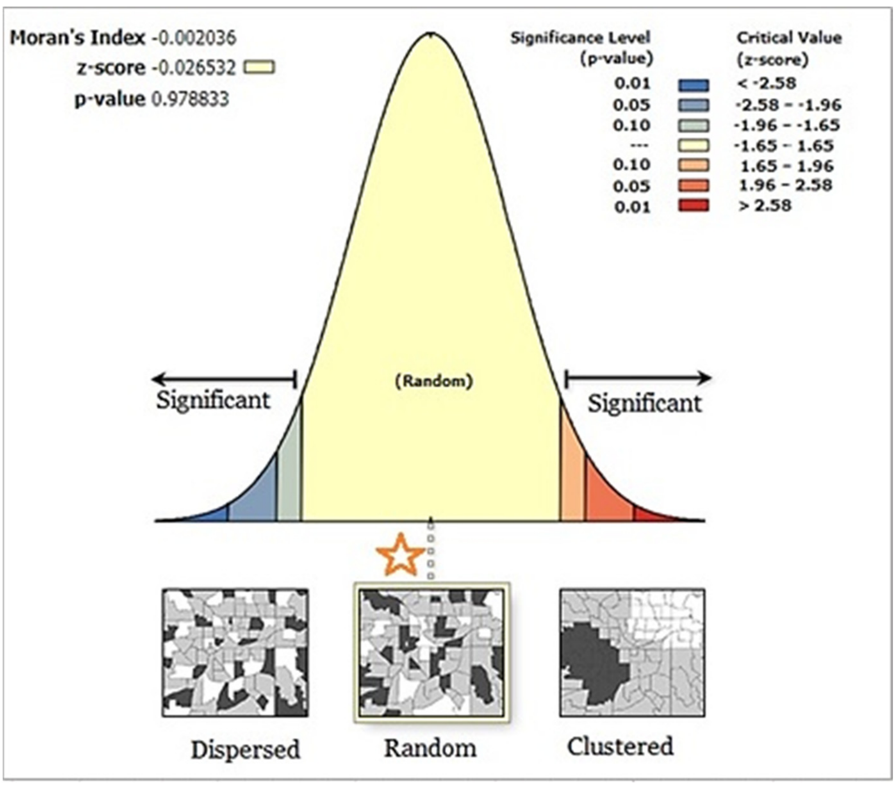


Figure 6. Moran's I Index and Residual Plots: Geographically Weighted Regression (GWR)

4.2 The Geographically Weighted Regression Model

In ordinary least squares regression (OLS) the response variable is a global linear combination of explanatory variables and residuals or the error term (Pohlman & Leitner, 2003). Formulaically, OLS can be expressed as:

$$\text{(OLS) } Y = B_0 + B_1X_1 + B_2X_2 + ...e \quad (3)$$

GWR produces local regression results based on spatial weights (Rząsa & Ciski, 2022). The difference is in the two keywords used: global for OLS vs. local for GWR. GWR corrects for autocorrelation by detecting and resolving spatial non-stationarity (Yellow Horse, et al., 2022). In this way, it significantly improves the model's fit by aligning fully with Waldo Tobler's first law of geography.

Formulaically, GWR can be expressed as:

$$\text{(GWR) } y_i = \quad \beta_0\,(u_i,v_i) + \; (x + a)^n = \sum_k^p \beta_k\,(u_i,v_i)\,x_{ik} + \varepsilon_i \quad (4)$$

where:

y_i — dependent variable at location i

x_{ik} — explanatory variable at location i

(u_i,v_i) — coordinate for location i

$\beta_0(u_i,v_i)$ — intercept location i

$\beta_k(u_i,v_i)$ — the coefficient for explanatory variable k at location i

ε_i — residual location i

Formula source: (Rząsa & Ciski, 2022)

GWR's main formulaic difference with OLS is that its regression coefficients ($\beta_k(u_i,v_i)$) are specific to our spatial units of analysis, i.e. the 634 EDHS 2016 sampling clusters.

5. Results

5.1 Women's Response to a Question on the Acceptability of Wife-beating

Table 1 shows regional (Kilil) level unweighted percentages of women by their responses to a question on the acceptability of wife-beating (see Figure 7 for the location of Kilils or regions/provinces). For the main administrative divisiona, the percentage of women who responded "yes" to EDHS question V744C ("beating is justified if wife argues with husband: yes or no?") ranged from a high of 51.6 (95 percent CI, 48.7, 54.5) in Afar Kilil to a low of 8.1 percent (95 percent CI, 6.8, 9.3) in the city administration of Addis Ababa. The second of the two city administrations in the country – Dire Dawa - has the second lowest percentage while the primarily urban Kilil Harari has the third lowest. These early results give an erroneous presumption of a uniformly low acceptance of wife-beating in urban or primarily urban areas. However, an in-depth analysis of these percentages in the forthcoming paragraphs will show that urban localities do not in fact have uniformly low wife-beating acceptance rates, but that there are pockets of high acceptance rates. Single-digit percentages of women gave a "yes" response in 89 of the 643 sampling clusters (17.8 percent of all clusters) (Figure 8A). In 146 clusters (22.7 percent of all clusters) the percentage of women responding "yes" was between 10.0 and 25.0, and in 220 sampling clusters (34.2 percent of all clusters) 26.0 to 50.0 percent of respondents said "yes". In 147 sampling clusters (22.9 percent of all clusters) 51.0 to 74.9 percent of women answered "yes". A supermajority of women (75+ percent) responded "yes" in the remaining 40 sampling clusters (6.2 percent of all clusters). Overall, the majority of women answered "yes" in 187 of the 643 clusters, i.e. in nearly a third (29.1 percent) of all clusters (Figure 8A).

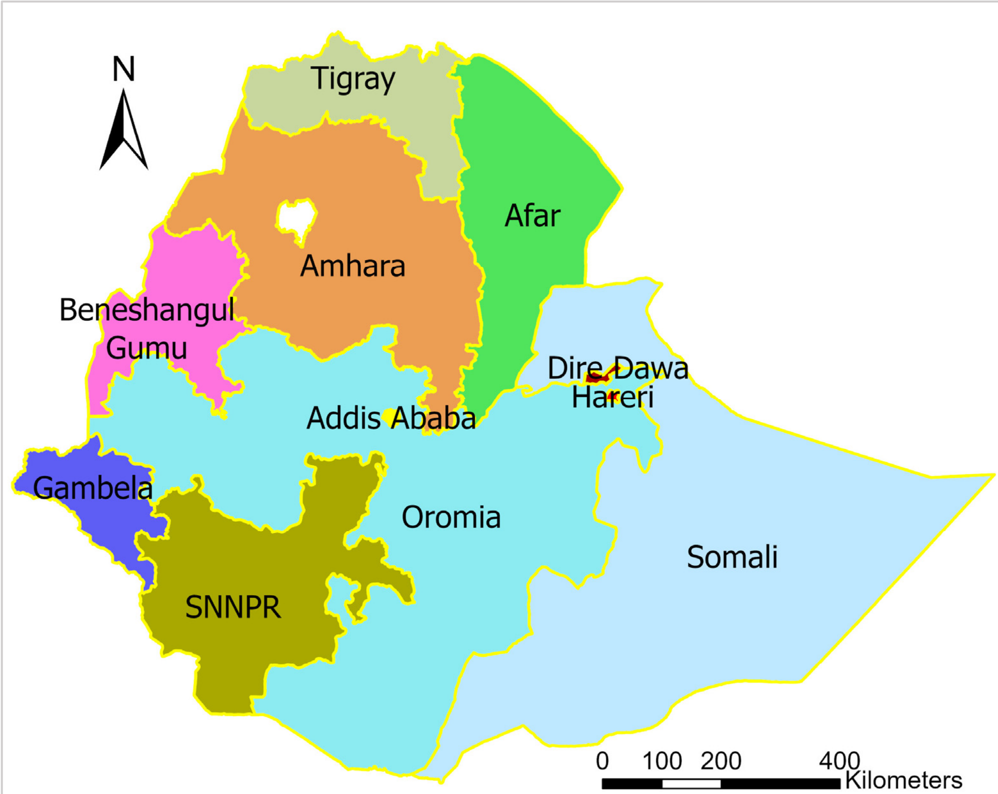


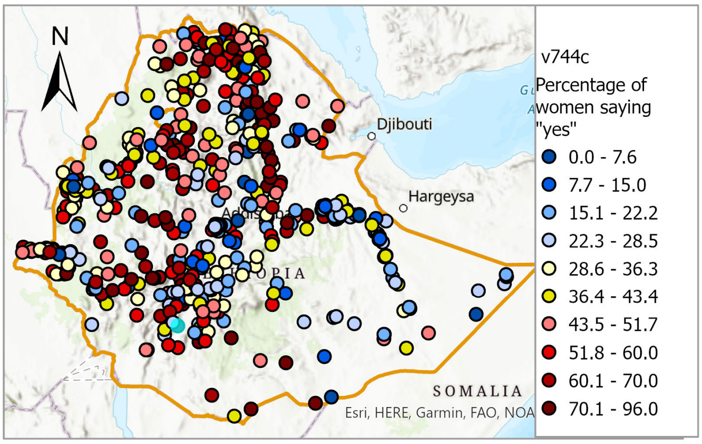
Figure 7. Ethiopia's Administrative Region Boundaries in 2016

Table 1. Regional Percentage of Women by Response to a Question on Wife-beating

Region	Sample size	No to wife beating	% No	Yes to wife beating	% Yes	Yes 95%LCL*	Yes 95%UCL*	Don't know	% Don't know
Afar	1,128	531	47.1	582	51.6	48.7	54.5	15	1.3
Oromiya	1,892	965	51.0	905	47.8	45.6	50.0	22	1.2
Tigray	1,682	894	53.2	783	46.6	44.2	48.9	5	0.3
SNNPR	1,849	1,014	54.8	823	44.5	42.2	46.8	12	0.6
Amhara	1,719	980	57.0	725	42.2	39.8	44.5	14	0.8
Gambela	1,035	614	59.3	414	40.0	37.0	43.0	7	0.7
Benishangul	1,126	725	64.4	400	35.5	32.7	38.3	1	0.01
Somali	1,391	913	65.6	446	32.1	29.6	34.5	32	2.3
Harari	906	654	72.2	243	26.8	23.9	29.7	9	1.0
Dire Dawa	1,131	879	77.7	239	21.1	18.8	23.5	13	1.1
Addis Ababa	1,824	1,670	91.6	147	8.1	6.8	9.3	7	0.4
Total	15,683	9,839	62.7	5,707	36.4	35.2	36.7	137	0.9

*LCL stands for lower confidence level and UCL stands for upper confidence level.

The next set of results relates to a global R^2 of 0.43 for all 643 clusters after every single one of the clusters was evaluated against 72 neighboring clusters at a national scale (hence the use of the terms global R^2), as well as local R^2s that varied from near zero for some clusters to over 0.6 for others with one cluster having the highest R^2 of 0.71 (Figure 8B). In Figure 9A, sampling clusters with R^2 greater than 0.5 are selected.



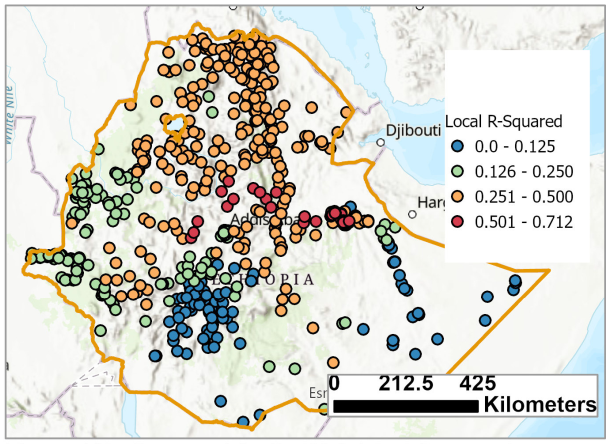
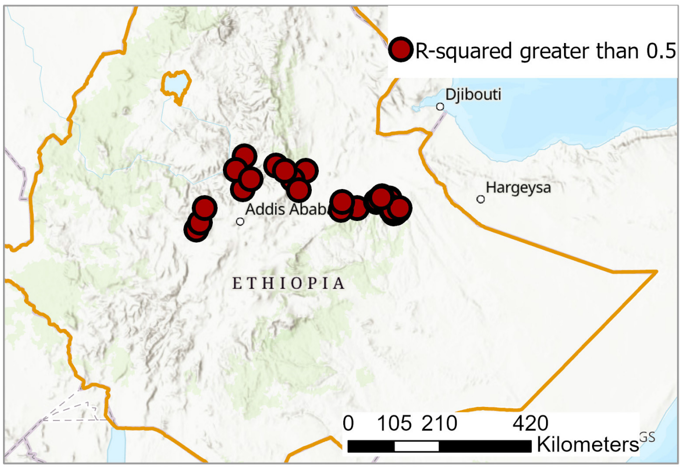


Figure 8A. percentage of women answering “yes” to a question on the acceptability of wife-beating

Figure 8B. Local R-squared from geographically weighted regression (GWR)



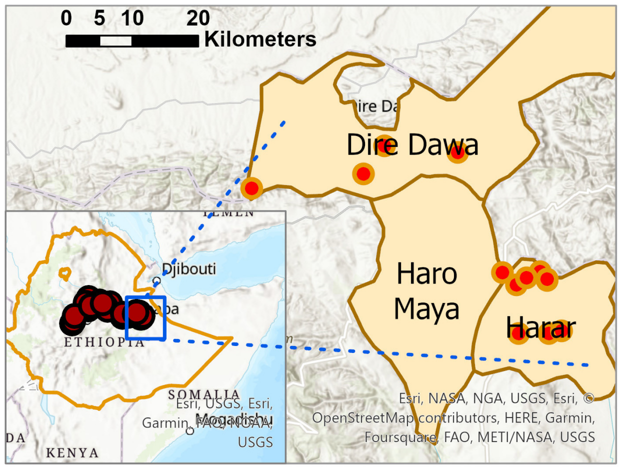


Figure 9A. Local R-squared >0.5, geographically weighted regression (GWR)

Figure 9B. Final selection of sampling clusters

5.2 Final Selection of Sampling Clusters

The combined criteria of (a) $R^2 > 0.5$, (b) the majority of women agreeing that wife-beating was okay, and (c) the majority of women stating that they have no formal education, led to the selection of 17 sampling clusters (Figure 9B). However, five of the 17 finalists were removed due to Condition Number (CND) values greater than 30. CND greater than 30 is an indication that our explanatory variable (education) clusters spatially, suggesting the likelihood of local spatial multicollinearity and instability of results for the five sampling clusters that were removed. The general advice is to be skeptical of results for locations or features where CND is greater than 30 (ESRI, 2023).

Table 2. Results of the Geographically Weighted Regression (GWR) for 12 Sampling Clusters Meeting Study Criteria

Cluster No	*Wereda*	*% Wife-beating okay (y)*	*%No education (x)*	*Intercept (a)*	*Coeff (β)*	*Predicted (ŷ)*	*Residual*	*Std Res*	*Local R^2*	*CND* number*
68	Harar	60.0	60.0	6.8	0.58	41.7	18.3	1.1	0.55	17.2
580	Harar	64.0	76.0	6.4	0.60	51.9	12.1	0.7	0.56	16.6
501	Harar	54.2	87.5	7.0	0.58	57.4	-3.2	-0.2	0.54	17.6
329	Harar	66.7	54.2	6.1	0.62	39.8	26.8	1.6	0.57	16.8
357	Harar	80.0	60.0	6.6	0.60	42.7	37.3	2.3	0.55	17.6
495	Harar	60.0	60.0	6.2	0.62	43.3	16.7	1.0	0.57	17.1
419	Harar	56.0	52.0	6.6	0.60	37.9	18.1	1.1	0.55	17.6
610	Haro M.	92.6	92.6	5.6	0.65	65.7	26.9	1.7	0.59	17.0
288	Harar	66.7	66.7	6.5	0.61	47.1	19.5	1.2	0.56	17.6
441	Dire D.	54.2	91.7	4.9	0.51	51.3	2.9	0.2	0.51	17.0
166	Dire D.	64.3	71.4	4.9	0.54	43.7	20.5	1.3	0.52	16.1
311	Dire D.	63.6	63.6	4.8	0.56	40.2	23.5	1.5	0.51	15.7

*CND (Condition number) indicates the level of local autocorrelation of the independent (x) variable; CND <30 is desirable.

6. Discussion

Reviews conducted in this study revealed errors in existing spatial statistics or regression-based geographical studies of Ethiopia's demographic and health survey data. Most studies inappropriately used the global ordinary least squares (OLS) linear regression methodology despite findings of autocorrelation and in violation of Waldo Tobler's first law of geography. Tobler's law states that near things are more related, with greater likelihoods of autocorrelation than distant things (Martin C. & Fotheringham, A.S. 2009). The studies also ignored a common knowledge that, when it comes to spatial data, regression coefficients do not remain uniform globally (nationwide) but rather vary locally across the study landscape (Brunsdon, Fotheringham & Charlton, 2002).

The GWR model is increasingly favored as a spatial statistical measure of demographic and health data and has been applied to locations as diverse as Indonesia (Elin, Gede, & Mindra, 2020), Texas (Zhang, Wu, & Chow, 2021), Arizona (Oshan, Smith, & Fotheringham, 2020), and Senegal (Ndiath et al, 2015). Conceptualization of the OLS regression involves the use of inverse (Euclidean) distance. For GWR, there are two approaches one can follow: 1) the distance band method, or 2) the nearest neighbor method. In the second method, the number of neighbors is either user-defined or derived by way of a "golden search" – a procedure where the ArcGIS Pro software determines the optimum number of neighbors as defined by the lowest Akaike Information Criterion (AIC) (ESRI, 2023). In this study, the number of neighbors with the lowest AIC was 72. This means that each of the 643 sampling clusters was evaluated against 72 neighboring clusters.

The study identified 12 sampling clusters located in three contiguous Weredas (districts) in the administrative divisions of Oromiya Kilil (region/province), Dire Dawa City, and Harari Kilil, all located in the highlands of eastern Ethiopia. These clusters are distinguished by: (a) the majority of women respondents stating that wife-beating was an acceptable practice, (b) the majority of women in those same clusters reporting a status of no formal education, (c) local R2 of 0.5 or greater when with each sampling cluster evaluated against 72 of its neighboring clusters in the GWR k-nearest-neighbors modeling environment and (d) CND value of less than 30. The residual column in Table 3 shows that in all but one of the 12 clusters, the model predicted a lower acceptance of wife-beating given the educational status of women in each of those clusters. In cluster 357 (Harar Wereda), the observed percentage (80) is nearly double the predicted percentage (42).

As the finalist Weredas were selected through spatial decomposition, they may be viewed as candidates for ground-level actions to implement scalable policy solutions aimed at protecting women against spousal abuse. Three-fourths of the selected Weredas are in Harari Kilil (Table 2). Located in this Kilil is the famous walled city of Harar with a rich history of interactions with central Ethiopia, the Arabian Peninsula, the Indian subcontinent, and Greece, as well as brief occupations by Egyptians (1875), and Italians during their invasion of Ethiopia in the first half of the 20th century (Hecht, 1982; Insoll, 2017). It is unclear if such a history and/or the facts contained in the reporting by Waldron (1975) have contributed to most of the selected sampling clusters being from Harar. While emphasizing its Islamic tradition, Waldron described Harar's historical beginnings as very much isolated or island-like, with tenuous links, both physically and symbolically, with surrounding ethnic groups. It is also unclear whether Waldron's characterizations highlighting Harari endogamous practices and traditions enhancing "the consciousness of being Harari" contributed to three-fourths of the selected clusters' locations being in Harar Wereda. Similar to Harar, the city administration of Dire Dawa has a predominantly Muslim population and is said to trace its origins to medieval times, although Dire Dawa's modern beginnings are linked more to the construction of the Ethio-Djibouti railway line which was completed in the first decade of the 20th century drawing-in Ethiopians of various ethnicities as well as foreign nationals (Haile, 2020). The mention of religion here and the observation that the province with the highest percentage of women responding "yes" to the appropriateness of wife-beating - Afar Kilil (see Figure 7 and Table 1) - is also predominantly Muslim, might tempt one to think of a religious connection with the12 finalist clusters. However, the perceived linkage would fail in regards to Somali Kilil where the population is also predominantly Muslim but where the highest percentage of women of any predominantly rural Kilil responded "no" to the question.

7. Conclusion and Recommendation

The main contribution of this study is the simplified application of the geographically weighted bivariate regression (GWR) in which, unlike the ordinary least squares regression (OLS), parameters are calculated using a model estimation that produces local results in variable geographic spaces. For details on model estimation and localized results, see Wheeler, D.C., & Páez, A. (2010). The biggest difference between GWR and OLS is that GWR produces a single global R^2 and multiple local R^2s matching the count of the geographic units in the analysis (643 sampling clusters in the case of this study). It is this ability to generate both global and local regression results, that makes GWR a far more appropriate spatial statistical measure than OLS for national landscapes such as Ethiopia's that are characterized by highly diverse local environments.

As confirmed by reviews of studies in other African countries as well as those conducted in Asia and South America, results obtained in this study are consistent with those that showed significant subnational variations in proportions of women who view wife-beating as an acceptable practice. Our results are also in agreement with studies that found the educational status of women among the main drivers of that sentiment. The study's reviews of literature on the consequences of wife-beating for both the physical and mental health of women, and the health of their children as well as its co-occurrence with pregnancy and other reproductive outcomes, revealed statistically significant links. This study did not, however, attempt to include health data from EDHS 2016 to quantify the strength of that association although the literature reviews we presented point to direct links in the Ethiopian context as well.

Further research involving explanatory variables not considered in this study is suggested after sufficient tests for multicollinearity of explanatory variables and detailed examinations of across-variable interactivity. Overall, the study on the social geography of women's attitudes to wife-beating in Ethiopia makes methodological contributions to spatial statistical studies of sociodemographic characteristics of all populations, especially those in developing countries such as Ethiopia where local socioenvironmental factors are highly varied. It also contributes to the literature on applied spatial statistics through its focus on GWR - a measure that can be used in conditions of significant local variations.

8. Limitations of the Study

The study is based on data that is seven years old. It is possible that Ethiopian women's views and opinions on wife-beating have shifted somewhat over these seven years to varying degrees depending on personal characteristics and the sociocultural environments surrounding them. Moreover, as the data are sample-based, they have margins of error. Additionally, the lack of previous spatial and temporal studies focused on geographic relationships between wife-beating and the educational status of Ethiopian women precluded comparisons of results by localized geographic spaces and of trends over time.

9. Availability of Data Used in this Study

The datasets used in this research can be downloaded from the main Demographic And Health Survey website located at:

https://dhsprogram.com/data/dataset/Ethiopia_Standard-DHS_2016.cfm?flag=0

10. Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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