BIOST 544 Final Project

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Introduction

Antenatal care (ANC) is essential in reducing maternal death. Between 30 to 50% of maternal results from insufficient antenatal care, while two-thirds of stillbirths are antepartum caused by maternal infections and pregnancy complications. The World Health Organization (WHO) recommends is four or more ANC visits during pregnancy for effective ANC service, specific to low-income countries[1]. In Kenya, over 90 percent of pregnant women receives at least one ANC visit during pregnancy. However, Kenya is currently one of the countries that have most neonatal deaths in the world[2].

There are researches assessing the coverage of four or more ANC visit at the national level. However, the aggregate national assessment will overlook the spatial variation across subnational areas, such as at the county level. With the wide healthcare disparity across areas within Kenya, it is essential to investigate the spatial variation of ANC4 visit coverage and provide a more comprehensive and granular analysis of ANC visit on subnational level. Also, few study investigate the association between the demographic factors and ANC coverage, which provides decision support for social justice policy making and resource allocation.

For this analysis, we want to use small are estimation (SAE) to map ANC visit at county-level. The ANC indicator we focus on is the indicator of four or more ANC visits, ANC4. We will also identify the demographic factors that are significantly associated with ANC4 utilization. The dataset to support the analysis is the 2014 Kenya demographic and health survey (KDHS 2014), which is publicly available.

The 2014 Kenya Demographic and Health Survey (KDHS) collected data for monitoring the population and health situation in Kenya. The 2014 KDHS is the sixth Demographic and Health Survey conducted in Kenya since 1989. This is the first KDHS that includes county- level data. The survey provides reliable estimates of fertility levels, marriage, sexual activity, fertility preferences, family planning methods, and other demographic information. The survey provides decision support for program managers and policymakers to evaluate and improve public healthcare system in Kenya[3].

Method

The 2014 KDHS interviewed 31,079 women age 15-49 and 12,819 men age 15-54 in the sampled households. The participants for the 2014 KDHS was selected from the existing national sampling frame, the Fifth National Sample Survey and Evaluation Programme (NASSEP V). The survey includes a total of 5,360 clusters, also known as Enumeration Areas. The sampling strata were derived from 47 counties, each of which was further stratified into urban and rural strata. Since Nairobi county and Mombasa county only have urban areas, the resulting total was 92 sampling strata. Samples were selected independently within each sampling stratum, using a two-stage sampling design. In the first stage, the 1,612 clusters were selected with equal probability from 5,360 clusters in NASSEP V frame, with 995 clusters in rural areas and 617 in urban areas. In the second stage, 25 households were selected from each cluster, with the resulting total 40,300 households. To adjust for the survey sampling design, the resulting data was weighted to be representative at the national, regional, and county levels[4]. The weight value for each individual measurement was used in the small area estimation to get the correct estimate of ANC utilization at subnational level.

To examine the association between demographic variables and ANC4 utilization, the general linear mixed effect models were fitted with each of demographic variable as predictor, ANC4 utilization as outcome interest. Based on previous research studies, the candidate demographic variables that may be potentially associated with ANC4 utilization were abstracted from KDHS 2014 data[5]. They included maternal education, birth order, household wealth, household residence type, marital status, ethnicity, parity, age at first marriage/cohabitation, place of delivery, sex of household head, religion, maternal age. For age at first marriage and maternal age, we dichotomize these two variable with the age cut point 18 years old. In this way, all the demographic variables included are categorical variable. The random effect was introduced at county level to adjust for the correlation of ANC4 utilizations within area. Likelihood ratio tests were conducted to test the null hypothesis that there is no association between certain demographic variable and ANC4 utilization. The general linear mixed effect was implemented using "glmer" function of "lme4" package in R software (version-4.0.4). The significance level for this analysis was set to 0.05. The regression coefficient, 95% Confidence Interval and p value was reported in the result section.

To estimate ANC4 utilization at county-level, small area estimation was used to develop spatial smoothing model over counties and provide a more robust estimate of ANC4 utilization than the survey design-based approach. The binomial Besag-York -Mollič (BYM) model for was built with ANC4 utilization as the binary outcome, including spatial random effect at county level, Independent and identically distributed (IID) non-spatial random effects at county level. Survey weights and sampling strata were specified to acknowledge the sampling design for unbiased variance estimate.

$$y_i|p_i \sim Binomial\ (n_i, p_i)$$
$$\theta_i = \log\left(\frac{p_i}{1-p_i}\right) = \mu + \varepsilon_i + Si$$
$$\varepsilon_i \sim_{iid} \mathrm{N}(0, \sigma_\varepsilon^2),\ [S_1, \ldots, S_n] \sim \mathrm{ICAR}$$

The spatial dependence, S, was represented through a spatial adjacency matrix of 47 counties and modelled by a conditional autoregressive (CAR) process. This adjacency matrix will be used for the spatial smoothing model.

The spatial smoothing model was implemented using "SUMMER" package in R software. The posterior mean estimate of ANC4 coverage from the spatial smoothing model was mapped at county level. Survey design-based direct estimate of ANC4 was also implemented and compared with the estimate from spatial smoothing model. We want to examine if the spatial smoothing approach substantially increases the precision of county-level ANC4 utilization estimate.

Results

Study population

A total population of 14949 women between 15 and 49 years had at least one pregnancy were included in this study. Most of women receive primary education (7843,52.5%), with only 1106 (7.4%) education higher than secondary.5% of the population are currently in union or living with a man. 68.9% of household head is male, with only 31.1% female. 51.7% of women have delivery at health facility, 48.3% at non-health facility. The percentages of household health at the poorest, poor, middle, rich, richest level are 30.2%, 20.4%, 17.6%, 16.5%, 15.3%, respectively. 34.5% of the households live in urban area, 65.5% of them live in rural area.

Table 1

	Overall (N=14949)
maternal education	
no education	2790 (18.7%)
primary	7843 (52.5%)
secondary	3210 (21.5%)
higher	1106 (7.4%)
marital status	
never in union	1164 (7.8%)
currently in union/living with a man	12332 (82.5%)
formerly in union/living with a man	1453 (9.7%)
religion	
roman catholic	2873 (19.2%)
protestant/ other christian	9474 (63.4%)
muslim	2185 (14.6%)
no religion	350 (2.3%)
other	41 (0.3%)
Missing	26 (0.2%)
parity	
0	54 (0.4%)
1	3066 (20.5%)
2	3384 (22.6%)
3	2658 (17.8%)
4	2038 (13.6%)
5	1381 (9.2%)
6	2368 (15.8%)
age of first marriage	
<18	5342 (35.7%)
>=18	8443 (56.5%)
Missing	1164 (7.8%)
sex of household head	
male	10306 (68.9%)
female	4643 (31.1%)
birth order	
Mean (SD)	3.48 (2.32)
Median [Min, Max]	3.00 [1.00, 15.0]
place of delivery	
health facility	7723 (51.7%)
non-health facility	7226 (48.3%)
ANC4	
Mean (SD)	0.545 (0.498)
Median [Min, Max]	1.00 [0, 1.00]
Missing	4 (0.0%)
household wealth	
poorest	4517 (30.2%)
poorer	3045 (20.4%)
middle	2628 (17.6%)
richer	2465 (16.5%)
richest	2294 (15.3%)
household residence type	
urban	5164 (34.5%)
rural	9785 (65.5%)
maternal age	
<18	545 (3.6%)
>=18	14404 (96.4%)

Demographic determinants of ANC4 utilization

From univariate linear mixed effect model, we concluded that women with higher education are more likely to receive ANC4 utilization ($p<0.0001$). Women currently in union with a man are more likely to receive ANC4 utilization ($p<0.0001$). The probability of receiving ANC4 in Women whose age at first marriage older than 18 years is higher than those younger than 18 years (odds ratio: 1.32 ; 95%CI, 1.23, 1.42). Women in more wealthy household are more likely to receive ANC4 service. Women who had delivery in non-health facility are less likely to receive ANC4 utilization (odds ratio: 0.44; 95% CI, 0.41, 2.14). The probability of receiving ANC4 in women whose maternal age older than 18 years is higher than those younger than 18 years (odds ratio: 1.26; 95% CI, 1.06, 1.51). Women whose household live in rural area have less ANC4 utilization than urban area. (odds ratio: 0.63; 95% CI, 0.58, 0.67)

Table 2

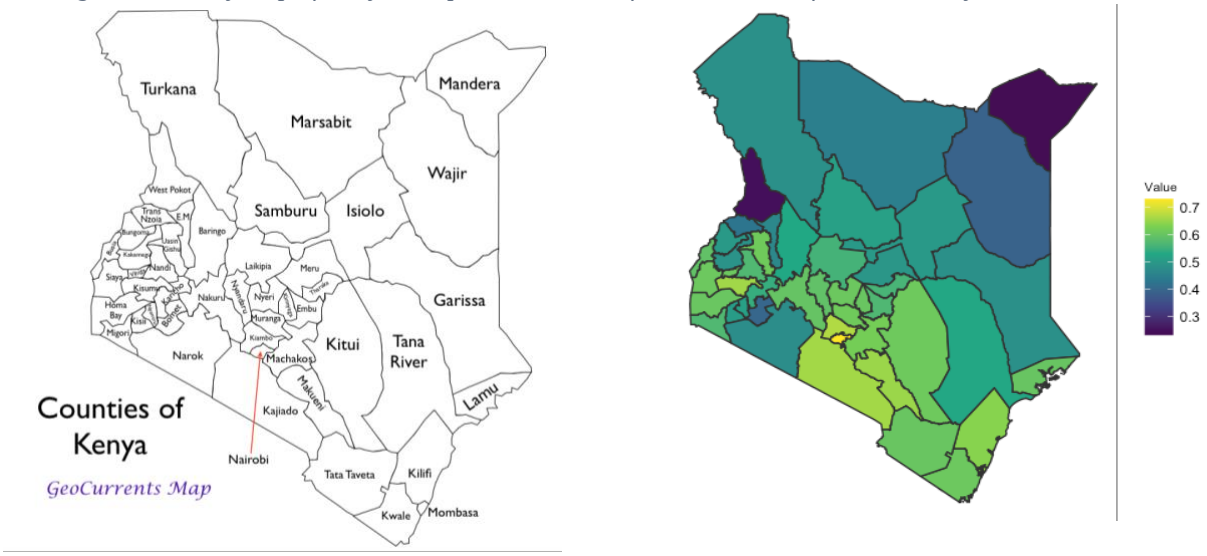
Variable	Variable category	Model coefficient (95% CI)	P value*
Maternal education	No education	ref	<0.0001***
	primary	0.42 (0.31,0.54)	
	secondary	0.85 (0.71,0.98)	
	higher	1.81 (1.62,1.99)	
Marital status	Never in union	ref	<0.0001***
	Currently in union with a man	0.34 (0.22,0.47)	
	Formerly in union with a man	0.13 (-0.03, 0.28)	
Age at first marriage	<18	ref	<0.0001***
	>=18	0.28 (0.21,0.35)	
Household wealth	poorest	ref	<0.0001***
	poor	0.32 (0.21,0.42)	
	middle	0.56 (0.46,0.67)	
	rich	0.81 (0.70,0.93)	
	richest	1.27 (1.15,1.40)	
Place of delivery	Health facility	ref	<0.0001***
	Non-health facility	-0.83 (-0.90, 0.76)	
Maternal age	<18	ref	0.009 **
	>=18	0.23 (0.06,0.41)	
Household residence	urban	ref	<0.0001***
	rural	-0.47 (-0.55,-0.40)	

* p value is derived from likelihood ratio test between full model and null model

ANC4 estimates at the county level

The county map of Kenya was shown below. ANC4 utilization estimates were calculate for all 47 counties(Figure 1). From the mapping of ANC4 at the county level, we can see a distinct spatial variation across counties. The ANC4 utilization rate is lowest in Mandera (0.23; 95% Credible Interval, 0.16,0.33), West Pokot (0.25; 95% Credible Interval, 0.20, 0.31), highest in Nairobi (0.73; 95% Credible Interval, 0.69,0.77), which is the capital city of Kenya. The counties around Nairobi-Kiambo, Kajiado, Makueni, also have a high rate of ANC4 utilization.

Figure 1: County map of Kenya and posterior mean of ANC4 estimate for each county



Both direct and smoothing estimates of ANC4 coverage and estimate variances were plotted in Figure 2. We can see estimates from both approach mostly consist with each other, while smoothing estimates have a much smaller variance. The posterior mean estimate for each county and 95% Credible interval was presented in Figure 3, along with survey-based direct estimate and 95% Confidence Interval. From Figure 3, we can see that spatial smoothing model has a much narrower interval than direct estimate, which substantially increase the precision of small area estimation.

Figure 2: Comparison of estimates and variances between direct model and smoothing model

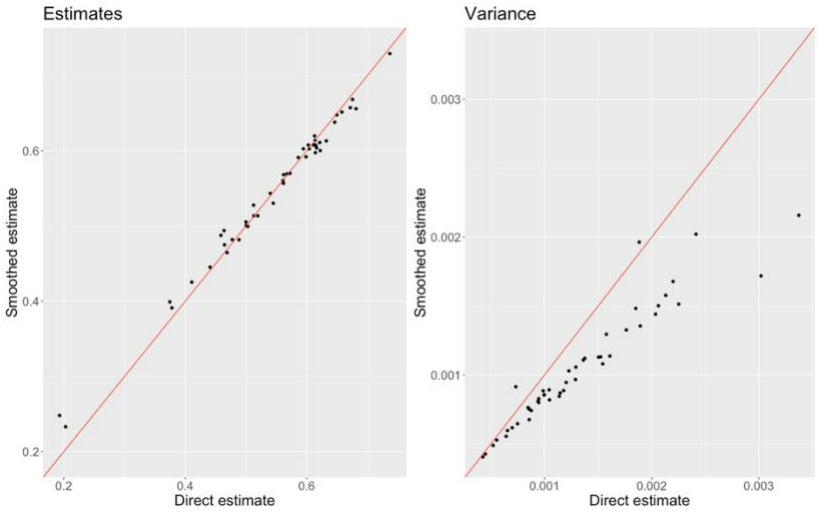
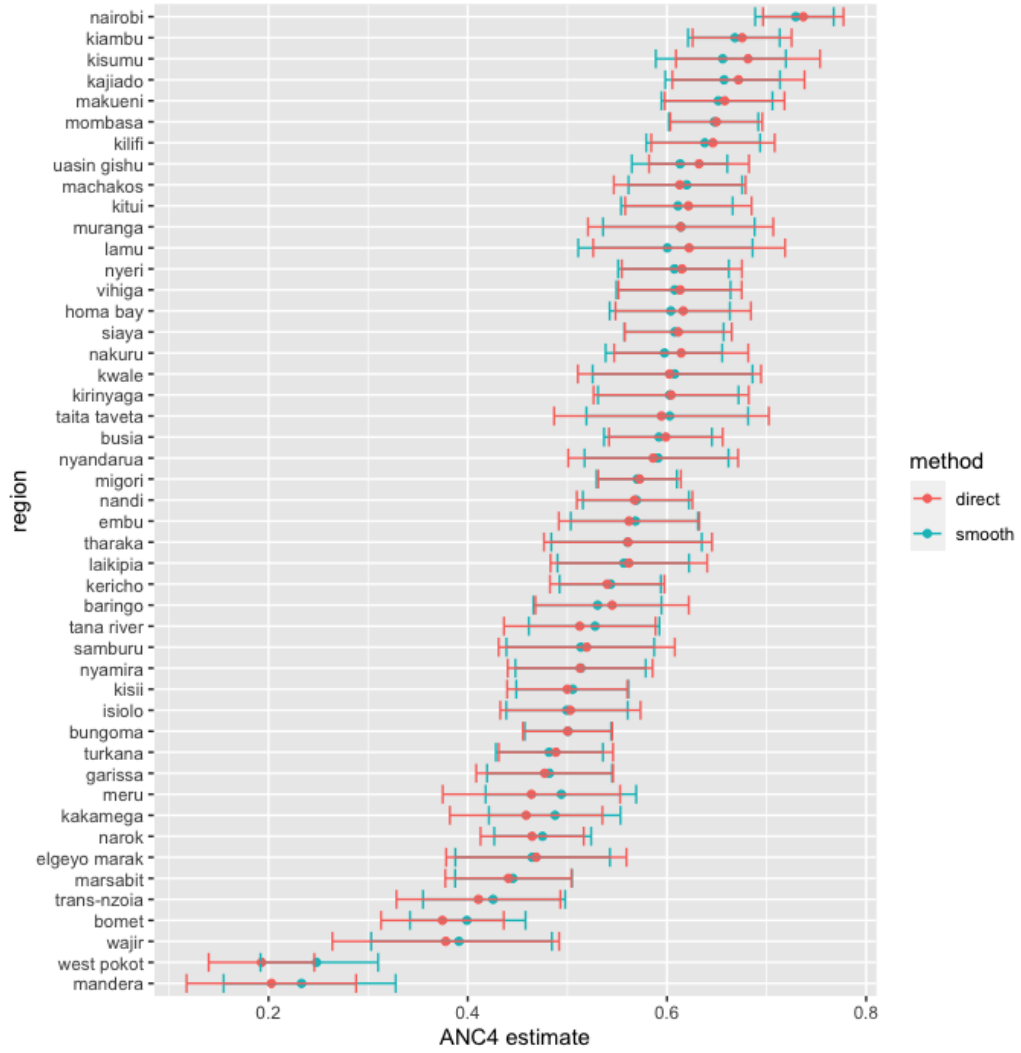


Figure 3: Direct estimate and spatial smoothing estimate (95% CI) of ANC4 for each county in Kenya



Discussion

From the study, we have strong evidence for association between ANC4 utilization and demographic variables- maternal age, maternal education, marital status, age at first marriage, place of delivery, household wealth, household residence delivery. It indicates that the socioeconomic factors substantially contribute to the maternal health and service coverage. There is still a huge gap of antenatal care accessibility that exists between low-socioeconomic group and high-socioeconomic group. From the small area estimation, high spatial variation of ANC coverage is present across country, with high ANC coverage around Capital city Nairobi, low ANC coverage around northeast border to Somalia and Ethiopia. More government resources should be allocated to the border area to improve the maternal care in most disadvantaged regions and narrow the healthcare service gap across counties in Keny

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