Small area estimation of antenatal care (ANC) coverage in Bangladesh: An application of multinomial multilevel modelling

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Abstract

This paper presents a small area estimation approach to assess antenatal care (ANC) coverage among reproductive-age women in Bangladesh. A multinomial multilevel logistic model is developed using district-level ANC coverage data, categorizing women into three groups: (i) those with no ANC visits (ANC0), (ii) those with 1-3 visits (ANC123), and (iii) those with four or more visits (ANC4+), as recommended by the World Health Organization (WHO). The model accounts for the distinct behavioral profiles of each group in relation to factors influencing maternal health coverage. In Bangladesh, as in many developing countries, the health system operates under a decentralized structure, making district-level statistics crucial for localized planning and decision-making to ensure health equity. Our proposed model-based estimators incorporate significant social, economic, and geographical disparities, identifying areas of improvement, stagnation, and decline. The model-based estimates demonstrate improved precision over direct estimates and provide valuable insights for designing targeted interventions to maximize impact. Additionally, a spatio-temporal extension of the multinomial multilevel logistic model is expected to yield further refined estimates, helping to uncover disparities in the trends of maternal health care access in Bangladesh.
Keywords: small area estimation; Bangladesh; multi-level modelling; ante-natal care (ANC) coverage.

1 Introduction

Maternal mortality is defined as deaths caused by complications during pregnancy or childbirth. Between 2000 and 2020, the global maternal mortality ratio (MMR) decreased by 34 percent, from 339 to 223 deaths per 100,000 live births, based on estimates from UN inter-agency data. This represents an average annual reduction rate of 2.1 percent. Although this progress is notable, it is only about one-third of the 6.4 percent annual reduction rate required to reach the Sustainable Development Goal (SDG) of reducing maternal deaths to 70 per 100,000 live births by 2030.

The situation in Bangladesh follows a similar trajectory, where according to the most recent estimates the MMR was 170 deaths per 100,000 live births. The World Health Organization (WHO) recommends a minimum of four ANC visits, based on reviewing the effectiveness of different models of service delivery. Having a sufficient number of ANC visits and receiving appropriate and timely care ensures that women are given the required resources to prepare for childbirth (Villar et al. 2001)[1]. Despite this, a majority of pregnant women in Bangladesh do not receive appropriate ANC services - more than 50 percent of women report not attending the recommended number at least four ANC visits (Rahman et al., 2017)[2]. But in fact, there are disparities in number and quality of

[1]WHO antenatal care randomised trial for the evaluation of a new model of routine antenatal care. Lancet 357 (9268):1551-64.

[2]Trends, determinants and inequities of 4+ ANC utilisation in Bangladesh. Journal of Health, Population and Nutrition; 36(1):2

ANC visits, and more starkly these differences are pronounced spatially at a subnational level.

2 Data and Methods

We model district level ANC0, ANC123 and ANC4$^+$ coverage data as a multinomial (tri-nomial) logistic mixed effects model (Lopez-Vizcaino et al., 2015[3]). The direct estimates of the counts of the women for the three groups are extracted from the 2017-18 Bangladesh Demographic and Health Survey data. Since the survey is representative only upto division level, district level estimates are not precise due to small sample size as well as ignorance of the districts in the survey sampling design. The small area estimation method employing multinomial logistic model with random effects is expected to provide more accurate estimates for all the districts. The number of the target population (women who had a last birth in 3 years preceding the survey) is extracted from the number of ever-married women available in the Census 2011 data. The SAE model is developed using the *MME* R package[4].

3 Preliminary Results

The dependent variable, Y_q, represents the number of women in each district classified into the three ANC categories. The category with no ANC visits is used as the reference group, reducing the Y_q vector to two dimensions (generally $q-1$) in modelling. To account for variability in socio-economic conditions and health infrastructure, district-level night-time light (NTL) data and the number of health centers (in the district) are incorporated into the model. These variables were found to be statistically significant, based on previous work (see, for example Das et al., 2024)[5] before including the division variable. Therefore, the two (remote sensed) covariates are retained in the model alongside the division variable.

Table 1 shows the regression coefficients and variance components from a multinomial mixed effects model, which evaluates the factors associated with the different categories of antenatal care (ANC) visits among women in Bangladesh. Both intercept parameters, comparing women with 1 to 3 ANC visits (ANC123) versus no visits (ANC0) and women with 4 or more ANC visits (ANC4+) versus no visits, are highly significant ($p < 0.001$). On the other hand, the availability of health centres and night light intensity, both scaled by 10^3, are not significant predictors of ANC visits. However, regional differences are evident: women in Barisal are less likely to have any ANC visits compared to no visits (ANC123 vs. ANC0: estimate $= -0.65$, p $= 0.01$; ANC4+ vs. ANC0: estimate $= -0.62$, $p = 0.05$). Conversely, women in Khulna, Rajshahi, and Rangpur are more likely to have 4 or more visits (estimates $= 0.99$, 0.56, and 0.79, respectively; all statistically significant with $p < 0.05$). In Sylhet, women are more likely to have 1 to 3 visits (estimate $= 0.55$, $p = 0.01$) but less likely to have 4 or more visits (estimate $= -0.81$, $p = 0.01$). The variance components for the district level random effects are significant (ANC123 vs. ANC0: $\sigma^2_{u1} = 0.81$; $ANC4+$ vs. ANC0: $\sigma^2_{u1} = 1.05$; both $p < 0.001$), indicating substantial variability in ANC utilization across divisions.

Table 2 compares the performance of direct (DIR) and small area estimation (SAE) estimators at both the division and national levels. The model-based estimates align closely with the direct estimates for ANC visits across different categories at both levels. Taken together with the regression coefficients in Table 1 , further supports this. The divisions of Khulna, Rajshahi, and Rangpur, located in the western part of the country, exhibit comparatively higher rates of ANC4+ coverage than those in the eastern part. This regional disparity is also confirmed by the spatial map in Figure 2. Additionally, the three hilly districts in the southeastern region have lower ANC4+ and higher ANC0 rates, which are directly linked to their limited access to healthcare facilities.

[3]Small area estimation of labour force indicators under a multinomal model with correlated time and area effects

[4]https://cran.r-project.org/web/packages/mme/index.html

[5]Improved Estimates of Child Undernutrition Trends in Micro-level Administrative Units in Bangladesh Using Remote-Sensed Data, Journal of Population Economics, to appear

Table 1: Regression coefficients and variance component obtained from multinomial mixed effects model

	ANC123 vs ANC0		ANC4$^+$ vs ANC0	
Variable	Estimate	p.value	Estimate	p.value
Intercept	1.79	< 0.001	1.32	< 0.001
Health centre$\times 10^3$	0.15	0.84	1.53	0.25
Night light$\times 10^3$	-1.02	0.94	21.01	0.24
Division: Barisal	-0.65	0.01	-0.62	0.05
Division: Chittagong	-0.04	0.81	-0.38	0.12
Division: Khulna	0.46	0.10	0.99	< 0.001
Division: Mymensingh	-0.30	0.17	-0.20	0.50
Division: Rajshahi	0.36	0.12	0.56	0.05
Division: Rangpur	0.11	0.64	0.79	0.01
Division: Sylhet	-0.55	0.01	-0.81	0.01
σ^2_{u1}	0.81	< 0.001	1.05	< 0.001

In Figure 1 (first row), we compared district-level ANC coverage using the direct estimator (DIR) and the model-based small area estimator (SAE). For the ANC123 category, the SAE estimates closely matched the direct estimates. However, the model slightly overestimated the proportion of women with no ANC visits (ANC0) and slightly underestimated those with 4 or more visits (ANC4+). This over- and under-estimation is attributed to several districts having zero women in the ANC0 category. To provide a clearer comparison, we then plotted the expected counts instead of proportions (second row of Figure 1), which showed a close match between the SAE and direct estimates for both the ANC123 and ANC4+ categories.

Figure 3 illustrates the spatial distribution of district-level ANC coverage, comparing direct and model-based estimates for the different ANC categories in Bangladesh. For the ANC0 category, the model-based estimates provide smoother results than the direct estimates. Some districts had few or no women in the ANC0 category in the direct estimates, but the model effectively smoothed these estimates. In contrast, the differences between the direct and model-based estimates for the ANC123 (1-3 visits) and ANC4+ (4 or more visits) categories were minimal (due in part to the relatively larger number of women in these categories).

Table 2: National and division level ANC coverage by the direct (DIR) and small area estimator (SAE)

	ANC0		ANC123		ANC4$^+$	
Division	DIR	SAE	DIR	SAE	DIR	SAE
Barisal	15.04	16.91	47.03	44.24	37.93	38.85
Chittagong	9.02	8.14	52.36	51.95	38.62	39.91
Dhaka	6.90	8.75	42.06	39.10	51.04	52.15
Khulna	4.02	4.98	38.99	37.84	56.99	57.18
Mymensingh	10.07	9.98	44.54	45.10	45.39	44.91
Rajshahi	5.24	8.14	46.84	44.91	47.92	46.95
Rangpur	5.13	6.79	35.65	35.40	59.21	57.81
Sylhet	14.54	14.51	50.90	50.86	34.55	34.63
Nation	8.01	8.99	44.99	43.74	47.00	47.28

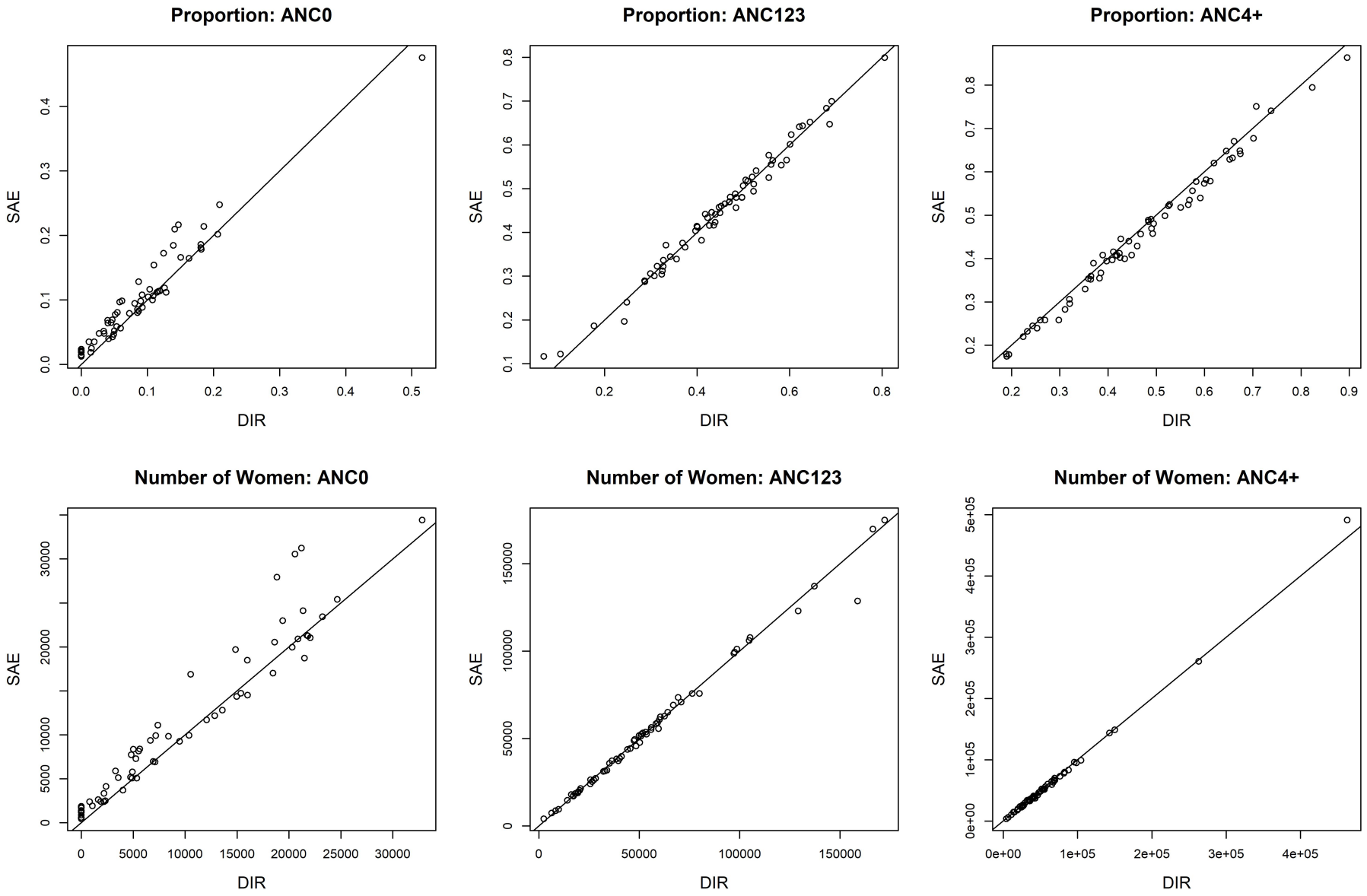

Figure 1: Comparison of direct estimates (DIR) and model-based small area estimates (SAE) for different categories of ANC visits. The first row represents the proportion of women, while the second row shows the total number of women.

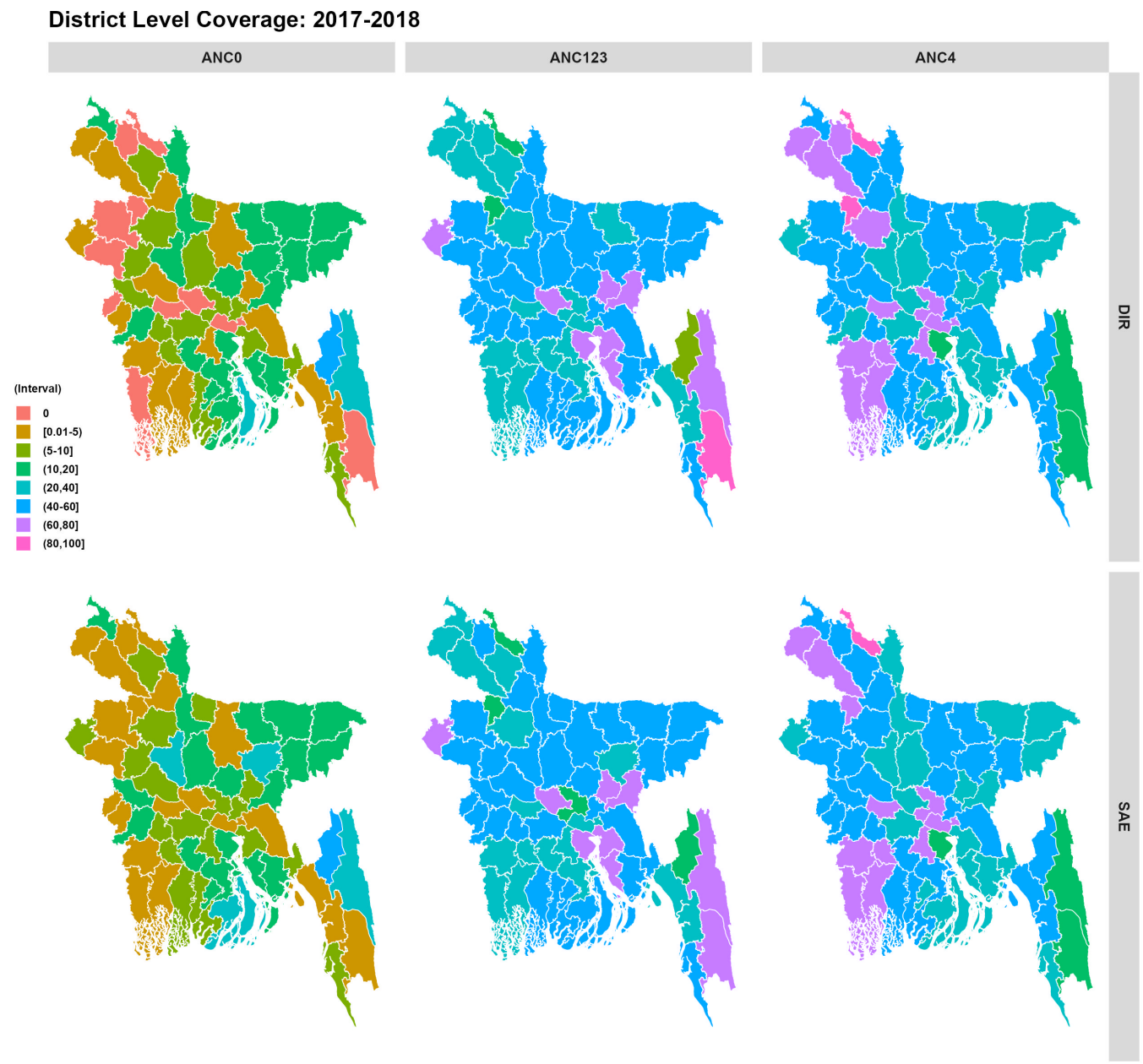

Figure 2: Spatial distribution of district level ANC coverage among Bangladeshi women, with the first row displaying the direct estimates (DIR) and the second row presenting the model-based small area estimates (SAE).

4 Conclusion

This study demonstrates the application of a multinomial mixed-effects model within a small area framework to estimate the proportions and counts of women grouped into three categories based on their antenatal care (ANC) visits during pregnancy. The primary advantage of this model is its ability to provide numerically consistent estimates for all three categories simultaneously, rather than fitting separate binomial logistic models for two groups (such as ANC0 or ANC4+). By including all three categories in the same model, the approach captures the interrelationships between the groups while accounting for area-level effects.

A spatio-temporal extension of this multinomial multilevel model is planned for district-level data from the nine rounds of BDHS data collected between 1993 and 2023. This extension can be developed within a Bayesian framework, following the approach of Boonstra et al. (2023)[6], using the *mcmcsae* R package.

[6]Multilevel time series modelling of mobility trends in the Netherlands for small domains. Journal of the Royal Statistical Society (Series A), 184(3), 789–1155.