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SMALL AREA ESTIMATION OF THE PERCENTAGE HOUSEHOLDS WITH FOOD EXPENDITURE SHARE MORE THAN 65 PERCENT IN LOW EXPENDITURE GROUP

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ABSTRACT

The right to get adequate food is a human right that must be fulfilled. Food insecurity is a problem that arises from not fulfilling food needs physically or economically. Food insecurity and poverty are interrelated. The United Nations prioritizes the elimination of poverty as the first goal and achieving food security as the second goal in the Sustainable Development Goals. In 2022, East Java had the highest percentage of households with a food expenditure share more than 65 percent in Java. The availability of data by expenditure group illustrates the economic status of households will assist the government in making targeted policies. However, the calculation of direct estimates at the regency level has not shown good precision, characterized by estimates with an RSE >25 percent. Therefore, this study aims to implement SAE HB Beta to improve the precision of the direct estimator. The result shows that SAE HB Beta produces a more precise estimation.

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1. INTRODUCTION

Food is a basic human need that must be fulfilled because it has an important role in maintaining the nation's survival [1]. The right to get adequate food is a human right that must be fulfilled. Hunger is one of the consequences of low food security [2]. Based on a report issued by Economist Impact in 2022, Indonesia's Global Food Security Index score is in the 63rd position out of 113 countries, which is 60.2 points [3]. This score only increased by 1.7 points compared to 2021 and is still below the world average of 62.2 points and lower than the Asia Pacific average of 63.4 points. Meanwhile, Indonesia's position among ASEAN countries is still below of Singapore, Malaysia, and Vietnam.

The efforts to improve food security became one of the commitments stated by the Group of 20 (G20) member countries at the Summit held under the Indonesian presidency in 2022 [4]. It is due to the perception that the world is experiencing an acute food crisis that will continue until 2023, threatening the achievement of the 2030 Sustainable Development Goals.

In Indonesia, the level of food security is measured through the Food Security Index. One of the constituent indicators of the IKP is the percentage of households with a food expenditure share more than 65 percent. This indicator indirectly represents welfare levels. The higher the level of community welfare, the lower the food expenditure share [5]. Low-income households allocate most of their income to fulfil basic needs, including food. Conditions when food needs are unmet will result in food insecurity [6].

Food insecurity and poverty are interrelated. Food insecurity can lead to poverty and vice versa. The United Nations (UN) has prioritized the elimination of poverty as the first goal and achieving food security as the second goal in the Sustainable Development Goals (SDGs). In Indonesia, eliminating poverty and achieving food security are top priorities in the 2005-2025 RPJPN and among the policy directions of the 2020-2024 National Medium-Term Development Plan [7].

Java is an island in Indonesia with many advantages, such as the highest level of development progress, the centre of economic activity, rapid economic growth, and complete facilities and infrastructure. Under these conditions, people in Java Island should ideally have easy access to their needs, including their food needs. However, based on food access from the economic side, using the indicator of the percentage households with a food expenditure share more than 65 percent, East Java has the highest percentage of households with a food expenditure share more than 65 percent in Java, at 31.23 percent [8]. The National Food Agency has determined that if the share of food expenditure is greater than 65% of total expenditure then the distribution of household expenditure is categorized as poor [9]. It shows that the level of food security in East Java Province from the aspect of economic affordability (access) is still not good compared to other provinces in Java Island.

The poor and vulnerable to poverty are population groups that need special attention in efforts to eliminate poverty and food insecurity. Target 2.1 of the SDGs prioritizes eliminating hunger due to food insecurity and ensuring access to food, especially for the poor and vulnerable groups. In addition, Sinaga et al, in their research on Java Island, stated that food insecurity is still widely found in population groups with moderate and low-income categories [10].

The indicator of the percentage of households with a food expenditure share more than 65 percent in the low expenditure group can indirectly illustrate the level of welfare in low-income communities. A high percentage of households with a food expenditure share more than 65 percent may indicate a low average household income or relatively high food prices. For households with low-income levels, this can lead to food insecurity if there is a sudden increase in food prices, pushing people into poverty and hampering poverty alleviation efforts [11].

To achieve the first and second goals of the SDGs and the targets contained in the national development plan, Indonesian Government needs to immediately address issues related to poverty and food insecurity, especially in priority groups. To support these efforts, the government needs the availability of accurate data as a basis for targeted policy making, which it can use data the percentage of households with a food expenditure share more than 65 percent in the low expenditure group. However, this data is not yet available, so estimation is needed.

The data source used to calculate the percentage of households with a food expenditure share more than 65 percent in the low expenditure group was obtained from the National Socio-Economic Survey (Susenas) in March. This survey is designed to provide estimation up to the regency level. However, when

estimation is carried out on subpopulations such as expenditure groups, it will not necessarily produce a good RSE value [12]. The direct estimation of the percentage of households with a food expenditure share more than 65 percent in East Java still has an RSE of more than 25 percent. It can happen because the sample used is insufficient, so the estimations are less accurate. One alternative that can be tried is the Small Area Estimation (SAE) method. SAE is a statistical method for estimating parameters from subpopulations with relatively small sample sizes [13]. In SAE, two essential things must be considered: how to get good enough parameter estimation in an area with a relatively small sample size and the estimated value of the variance of the parameter estimates obtained.

Data on the percentage of households with a food expenditure share more than 65 percent in the low-expenditure group includes data in proportions with a value range of 0-1. Therefore, the appropriate method used to estimate the percentage of households with a share food expenditure of more than 65 percent in the low-expenditure group is a method that accommodates a model with a Beta distribution. This study will estimate using the Hierarchical Bayes (HB) method with Beta distribution.

Based on this explanation, this study aims to estimate the percentage of households with a food expenditure share more than 65 percent in the low expenditure group at the regency level using the SAE HB Beta method.

2. RESEARCH METHODS

The interest variable (Y) in this study is the percentage of households with a share of food expenditure more than 65 percent in the low expenditure group. The percentage of households with a food expenditure share more than 65 percent is a proxy indicator of household food security measures, mainly related to food access. Households with a food expenditure share of more than 65 percent indicate that the household's expenditure distribution is poor [14]. **Equation (1)** below is a formula to calculate the percentage of households with a food expenditure share more than 65 percent in the low expenditure group:

$$\mathrm{A} = \frac{\mathrm{B}}{\mathrm{C}} \times 100 \tag{1}$$

With

A: percentage of households with food expenditure share $> 65\%$ in the low expenditure group
B: number of households with food expenditure share $> 65\%$ in the low expenditure group
C: total households in the low expenditure group

On the other hand, the candidate of auxiliary variables (X) in this study consist of:

1. Percentage of villages with rural status (X_1),
2. Percentage of villages with the main source of income from agriculture, forestry and fisheries (X_2),
3. Percentage of villages with non-asphalt/concrete road surface access (X_3),
4. Percentage of families who are not electricity users (X_4),
5. Number of families using gas fuel (X_5),
6. Percentage of villages with adequate defecation facilities (X_6),
7. Percentage of villages with adequate water sources (X_7),
8. Number of slum families (X_8),
9. Number of natural disasters (X_9),
10. Ratio of high school per 10,000 high school age population (X_{10}),
11. Ratio of tertiary institutions per 10,000 population aged PT (X_{11}),
12. Ratio of health facilities per 10,000 population (X_{12}),
13. Ratio of medical personnel per 10,000 population (X_{13}),

14. Number of sufferers of extraordinary events (X_{14}),
15. Number of indigent certificates issued (X_{15}),
16. Ratio of economic facilities per 10,000 population (X_{16}),
17. Number of credit facilities (X_{17}).

The data used in this study obtained from Susenas (The National Social-Economic Survey) on the Consumption and Expenditure Module in 2023 for the interest variable. Meanwhile, the auxiliary variables obtained from the 2021 Village Potential (Podes) data. This study was conducted in 38 regencies or municipalities in East Java Province.

2.1 Small Area Estimation (SAE)

An area (domain) is called small if the sample size in the area is insufficient for direct estimation to obtain an estimator with sufficient precision [12]. In some cases, there are even areas that have no sample at all. The term "small area" refers to a subpopulation that is directly estimated but the resulting estimator does not have sufficient precision. These subpopulations are not just for geographic area characteristics but also include socio-demographic group characteristics or other characteristics.

SAE is a statistical method for estimating parameters from subpopulations with relatively small sample sizes [13]. Small area models are divided into two types of models based on the availability of accompanying variable data, namely area level models and unit level models [12]. In SAE, there are two important things, namely, how to get good enough parameter estimation results in an area that has a relatively small sample size and how to get the estimated value of the variance of the parameter estimates obtained.

2.2 Hierarchical Bayes Beta Model

The HB Beta model can overcome estimation with SAE on proportion data. This model assumes the sampling model is beta distributed and the linking model used is the logit link function. The beta distribution assumption is chosen in this modelling because this distribution has properties like proportion data; the range of values is between 0 and 1, and the distribution tends to be asymmetrical [15]. Meanwhile, the logit link function ensures that the resulting proportion estimator has a value in the 0-1 range. The following is the SAE HB Beta model equation at the area level:

1. Sampling model

$$\hat{\theta}_i|\theta_i, \boldsymbol{\beta}, k, \sigma_v^2 \sim^{ind} Beta(a_i, b_i), \quad i = 1, \dots, m$$

With

$\hat{\theta}_i$: estimator of proportion parameter for small area i
θ_i : proportion parameter for small area i
a_i, b_i : beta distribution parameter, with $a_i = \theta_i k$; $b_i = (1-\theta_i)k$ such that $E(\hat{\theta}_i) = \theta_i = \frac{a_i}{a_i+b_i}$.
The notation k is a constant that is assumed to be gamma-distributed with parameters g_1 and g_2 or can be written $k \sim Gamma\ (g_1, g_2)$.

2. Linking model

$$logit\ (\theta_i)|\boldsymbol{\beta}, \sigma_v^2 \sim^{ind} N(\boldsymbol{x}_i^T \boldsymbol{\beta}, \sigma_v^2), \quad i = 1, .., m$$

with $\beta_j \sim N(\mu_{\beta_j}, \sigma_{\beta_j}^2)$ and $\sigma_v^2 \sim IG(c_1, c_2)$. IG is an acronym for Inversed Gamma distribution.

The main concept of the HB method in estimating parameters for small area is in the posterior distribution. However, the posterior distribution of parameters is not always obtained in closed form [16]. So, analytically solving parameter estimation calculations takes a lot of work. Therefore, the model can be solved numerically with the Markov Chain Monte Carlo (MCMC) method using the package available in R software.

2.3 Data Analysis Procedures

1. Data preparation

   Several things were done in the data preparation stage: filtering the Susenas March 2023 data for East Java and households with monthly per capita expenditure under cut off points, creating food expenditure share variables, and aggregating Podes 2021 data to create auxiliary variables at the regency or municipality level.

2. Direct Estimate

   In Susenas, y_{ihlm} is the percentage value of households with a food expenditure share more than 65 percent in a household *m*, census block *l*, strata *h*, regency or municipality i, and $w_{ihlm}^{(adj)}$ is weights that have been adjusted, so direct estimate ($\hat{\theta}_i^{direct}$) is obtained by the following **Equation (2) [17]**.

$$\hat{\theta}_i^{direct} = \frac{\sum_h \sum_l \sum_m w_{ihlm}^{(adj)} y_{ihlm}}{\sum_h \sum_l \sum_m w_{ihlm}^{(adj)}} \tag{2}$$

   Direct estimation was calculated using the survey package that available in the R software. The direct estimation then used to calculate the RSE value.

3. Indirect Estimate with SAE HB Beta

   a. Test the significance of the correlation between the directly estimated logit of the variable of interest and the candidate auxiliary variables.

   b. Checking the assumption of non-multicollinearity between significant auxiliary variables by calculating the Pearson correlation value.

   c. Select the auxiliary variables with stepwise regression for the best model.

   d. Establish the SAE HB Beta model with the help of the 'saeHB' package. Modelling is done by determining the value of *update*, *iteration*, *thin*, and *burn-in* until a convergent model is obtained.

4. Model Evaluation

   Model evaluation is done by comparing the RSE value of the direct and estimation with SAE HB Beta. The best model is the model that has a smaller RSE value. The following **Equation (3)** is formula for calculating the RSE value of direct estimation while **Equation (4)** is formula for HB Beta:

$$RSE\left(\hat{\theta}_i^{direct}\right) = \frac{SE\left(\hat{\theta}_i^{direct}\right)}{\hat{\theta}_i^{direct}} \times 100\% \tag{3}$$

$$RSE\ \hat{\theta}_i^{HB} = \frac{\sqrt{V[h(\boldsymbol{\theta})|\mathbf{y}]}}{\hat{\theta}_i^{HB}} \times 100\% \tag{4}$$

   description:

   $\hat{\theta}_i^{direct}$: direct estimator,
   $SE\left(\hat{\theta}_i^{direct}\right)$: standard error of direct estimator,
   $V[h(\boldsymbol{\theta})|\mathbf{y}]$: variance of *posterior*,
   $\hat{\theta}_i^{HB}$: expectation value of *posterior* ($E[h(\boldsymbol{\theta})|\mathbf{y}]$).

5. Mapping

   Mapping was conducted to see the spatial distribution of the results of the variable of interest estimation. This thematic map was created using QGIS software.

3. RESULTS AND DISCUSSION

3.1 Direct Estimate

The results of the direct estimation of the percentage of households with a food expenditure share more than 65 percent in the low expenditure group are still not precise. **Table 1** shows the direct estimation along with the RSE:

Table 1. The Direct Estimator Result with RSE

Regency	$\hat{\theta}_i^{direct}$	RSE	Regency	$\hat{\theta}_i^{direct}$	RSE	Regency	$\hat{\theta}_i^{direct}$	RSE
Pacitan	33.01	11.33	Pasuruan	57.08	7.21	Sampang	42.32	9.71
Ponorogo	26.57	15.09	Sidoarjo	11.27	29.57	Pamekasan	41.28	9.21
Trenggalek	32.53	11.15	Mojokerto	37.36	10.47	Sumenep	56.6	16.73
Tulungagung	26.37	15.16	Jombang	37.79	10.12	Kediri City	12.64	42.59
Blitar	26.04	12.53	Nganjuk	30.86	12.79	Blitar City	15.45	30.15
Kediri	38.91	9.35	Madiun	32.47	10.83	Malang City	11.62	30.9
Malang	39.21	7.75	Magetan	23.19	12.16	Probolinggo City	7.31	47.3
Lumajang	57.57	6.3	Ngawi	33.63	11.57	Pasuruan City	33.86	14.01
Jember	51.65	6.56	Bojonegoro	37.67	8.81	Mojokerto City	6.21	44
Banyuwangi	23.82	13.19	Tuban	46.68	9.17	Madiun City	3.61	56.23
Bondowoso	48.66	7.21	Lamongan	29.7	14.52	Surabaya City	15.16	24.02
Situbondo	53.33	7.27	Gresik	12.31	30.36	Batu City	15.3	35
Probolinggo	37.48	9.7	Bangkalan	55.93	8.91			

Ten regencies or municipalities in East Java have RSE values of more than 25 percent. This shows that the direct estimation of the percentage households with a food expenditure share more than 65 percent in the low expenditure group is not precise. For this reason, other methods are needed that can produce better estimates. One of them is applying the SAE method.

Data on the percentage of households with a food expenditure share more than 65 percent in the low expenditure group includes data in proportions after dividing it again by 100 percent. This data has a range of values between 0-1, so it is approached with a beta distribution. The connecting function used is the logit function to ensure that the resulting values are still within the 0-1 range. Therefore, the SAE HB Beta method is the appropriate method to estimate the percentage of households with a food expenditure share more than 65 percent in the low expenditure group.

3.2 Indirect Estimate with HB Beta

The SAE HB Beta method is more appropriate for this study. To get the best auxiliary variables, it is necessary to select the variables first. This stage starts from testing the correlation, checking the suitability of the correlation direction with the theory, checking multicollinearity through the Pearson correlation coefficient value, and selecting auxiliary variables with stepwise regression. Of the 17 proposed auxiliary variables, three were used in the modeling, namely the percentage of villages with rural status (X_1), the percentage of villages with proper defecation facilities (X_6), and the number of SKTM issued by the village government (X_{15}). **Table 2** shows that all parameters β are proven to affect the model significantly. This is indicated by the estimated parameter coefficient values in the range of 2.5 to 97.5 percent, none exceeding zero for all parameters β.

Table 2. The Coefficients of SAE HB Beta Model Parameter

Coefficient of Parameter Estimation	Mean	Standard Deviation	2.5 %	97.5 %
Intercept	4.8×10^{-1}	2.9×10^{-2}	4.6×10^{-1}	5.4×10^{-1}
b_1	1.7×10^{-2}	3.9×10^{-4}	1.6×10^{-2}	1.8×10^{-2}
b_6	-2.6×10^{-2}	2.8×10^{-4}	-2.6×10^{-2}	-2.5×10^{-2}
b_{15}	1.2×10^{-5}	1.1×10^{-6}	9.9×10^{-6}	1.4×10^{-5}

Estimation with SAE HB Beta is based on Bayesian inference that uses the prior distribution and likelihood function to obtain the posterior distribution. Using the Markov Chain Monte Carlo (MCMC)

technique, an accurate posterior distribution is obtained when the equilibrium condition is reached (when the algorithm converges), namely in experiments with 19 updates, 30,000 iterations, 19 thin, and 10,000 burn-ins. The following is the result of the converged diagnostic plot on the MCMC algorithm.

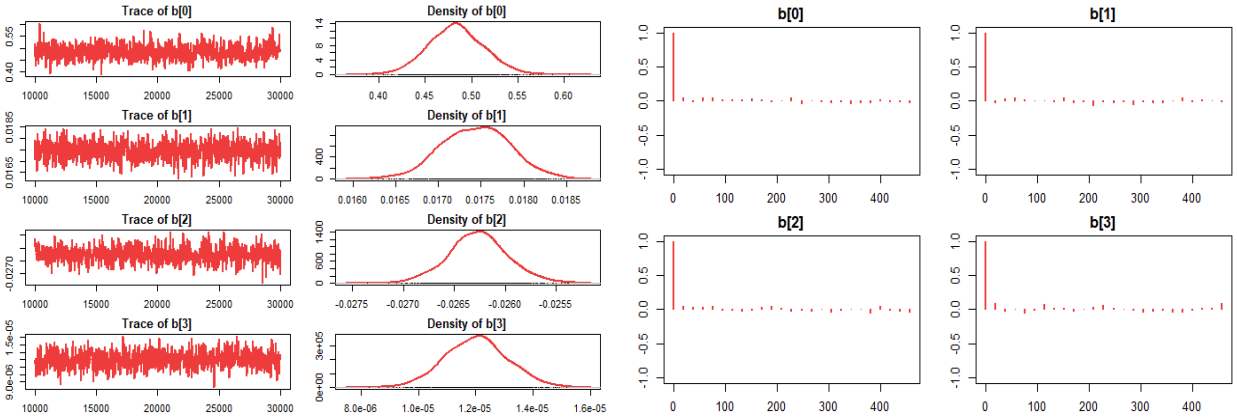

Figure 1. Diagnostic Plots on all Parameters
Data source: *the output of estimation parameter from R software*

Based on **Figure 1**, each parameter has a trace plot whose pattern is no longer periodic (stationary). Similarly, the density plot of each parameter is smooth and resembles a normal curve. In addition, the autocorrelation plot shows that for each parameter, the autocorrelation plot is cut off after the first lag.

The results of indirect estimation with SAE HB Beta show that the mean of the percentage of households with a food expenditure share more than 65 percent in the low expenditure group at the regency or municipality level in East Java is 31.61 percent. Meanwhile, the minimum value is 4.79 percent in Madiun Municipality, and the maximum is 56.70 percent in Lumajang.

Table 3. Descriptive Statistics Comparison of Direct Estimator and SAE HB Beta

Descriptive statistics	Direct estimator (%)	SAE HB Beta estimator (%)
Minimum	3.61	4.79
1st Quartile	17.39	17.22
Median	32.77	32.63
3rd Quartile	40.76	40.47
Mean	31.64	31.61
Maximum	57.57	56.70

Compared to the direct estimation shown in **Table 3**, the SAE HB Beta estimator have a smaller mean percentage. In general, the SAE HB Beta estimator still has the same pattern and estimation values that coincide with the direct estimator (see **Figure 2**). Based on the type of administrative region, the percentage of households with a food expenditure share more than 65 percent in the low expenditure group for regency is higher than municipality.

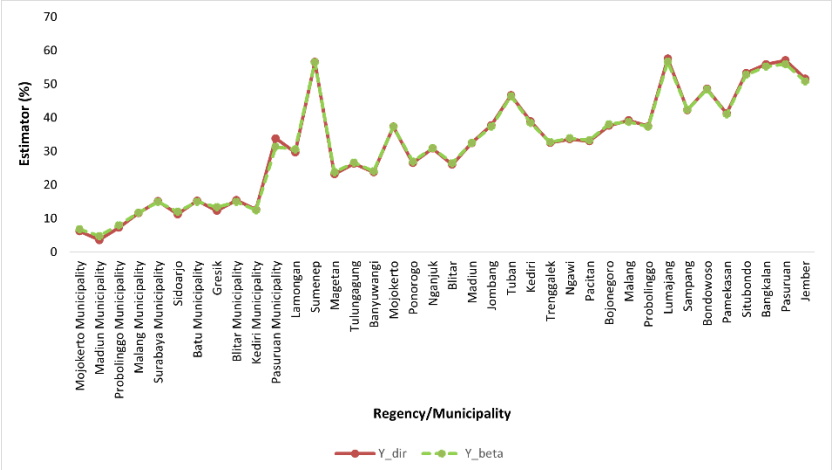

Figure 2. Comparison of Direct and SAE HB Beta Estimators

3.3 Evaluation of Direct Estimation and Indirect Estimation Based on Modelling Results

The estimations are evaluated by comparing the RSE values of direct estimation and HB Beta. **Table 4** below shows that HB Beta produces an estimator with a smaller average RSE than the RSE of the direct estimator.

Table 4. Descriptive Statistics of RSE Direct Estimation and SAE HB Beta Estimation

Descriptive statistics	RSE direct estimation	RSE SAE HB Beta estimation
Minimum	5.94	4.89
1st Quartile	9.58	6.53
Median	11.89	8
3rd Quartile	26.63	11.98
Mean	18.34	9.61
Maximum	52.32	27.26

Table 4 shows HB Beta's estimation has the smallest of mean RSE, 9.61 percent. Meanwhile, HB Beta's maximum RSE value is 27.26 percent. The following graph visually presents the improvement in the overall precision level.

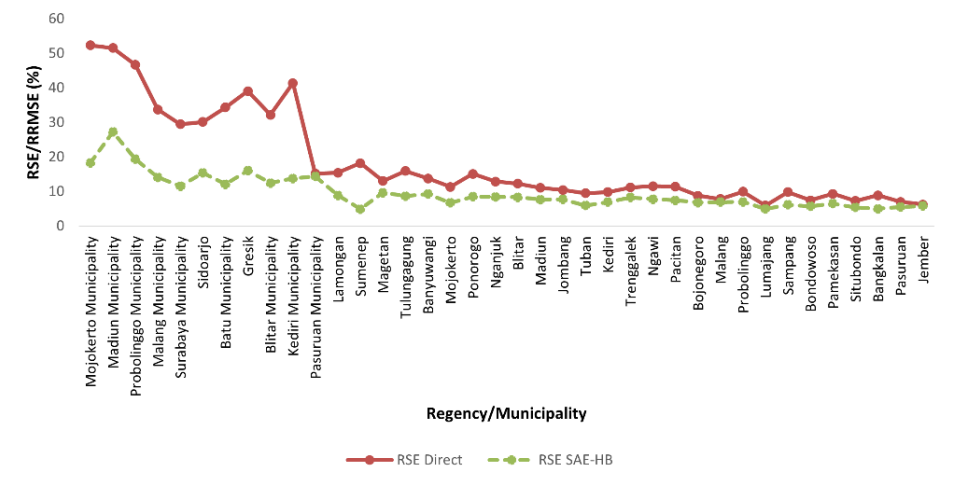

Figure 3. Comparison of RSE of Direct and SAE HB Beta Estimators

From the comparison in **Figure 3**, the direct estimation of HB Beta are more precise. **Table 5** shows the distribution of the number of regencies or municipalities in East Java based on the category of RSE.

Table 5. Number of Regency or Municipality in East Java by Category of RSE

Category of RSE	Direct estimation	SAE HB Beta estimation
RSE ≤ 25%	29	37
25%< RSE ≤50%	8	1
RSE > 50%	2	0

Table 5 shows that estimation with SAE HB Beta can significantly reduce the RSE value until only one region has RSE value above 25 percent. Based on the results of descriptive statistics, graphs and tables comparing the RSE values, it can be concluded that estimation with HB Beta is the best model in producing estimates of the percentage of households with a food expenditure share more than 65 percent in the low expenditure group of regency or municipality in East Java.

These results are in line with Yuniarty et al. 's research, which shows that the RRMSE value in the skew-normal SAE HB model is smaller than the direct estimation method **[18]**. In addition, Sukarsa and Gandhiadi's research showed that the HB method is the best method for estimating the proportion of poor households at the village level in Bali Province because it has the smallest MSE value compared to the Empirical Bayes (EB) and Empirical Best Linear Unbiased Prediction (EBLUP) methods **[19]**.

3.4 Mapping the Percentage of Households with Food Expenditure Share more than 65 Percent in Low Expenditure Groups Based on SAE HB Beta

To determine the distribution of the percentage of households with a food expenditure share more than 65 percent in the low expenditure group in East Java in 2023, the following thematic map is presented, grouped into six categories based on guidelines from Bappanas.

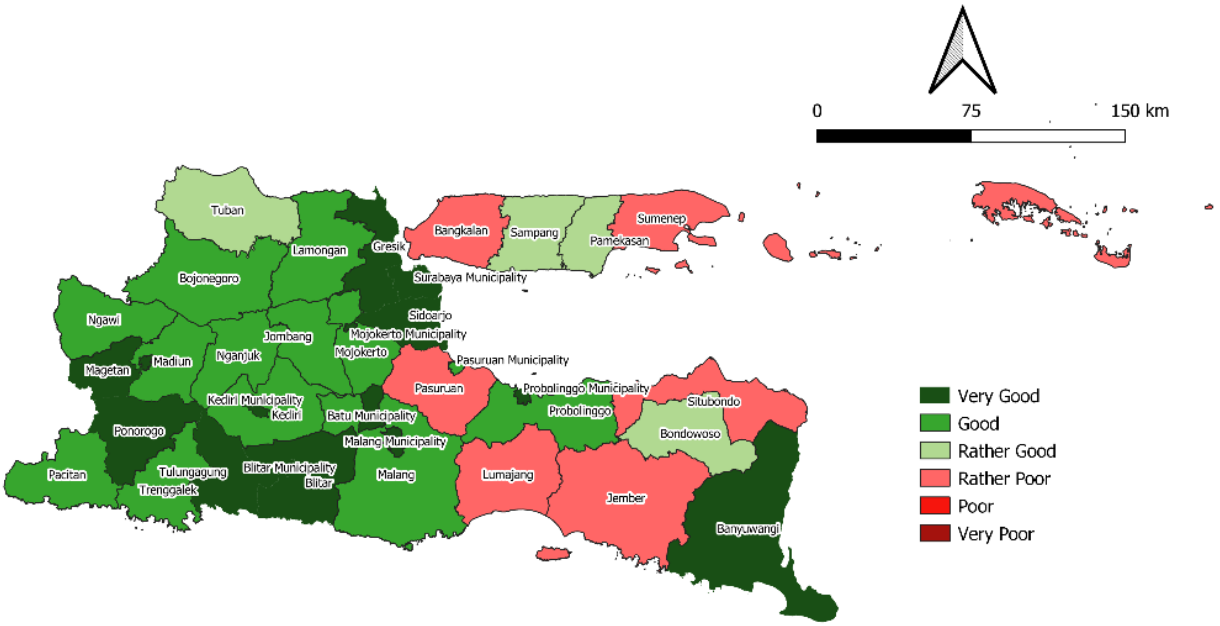

Figure 4. Thematic Map for Estimation with SAE HB Beta

Figure 4 shows that the estimation with SAE HB Beta show that in East Java, there are six areas which include the category of vulnerable to food insecurity (percentage ≥ 50): Lumajang, Sumenep, Jember, Bangkalan, Situbondo, and Pasuruan regency. Geographically, areas in the western part of East Java Province have low percentage values (food-secure regions). Meanwhile, areas in the eastern part of East Java Province have higher percentage values.

4. CONCLUSIONS

The results of the direct estimation of the percentage of households with a food expenditure share more than 65 percent in the low expenditure group show that ten of the 38 regencies or municipalities in East Java have a high RSE. Indirect estimation was calculated using the SAE HB Beta method. This method generally produces similar patterns and estimation values that coincide with the direct estimation. Lumajang regency has the highest percentage of households with a food expenditure share more than 65 percent in the low expenditure group in East Java. In contrast, Madiun municipality has the lowest percentage. Regency administrative areas tend to have higher percentage values than municipality areas. Evaluation of the estimation based on the RSE value showed that SAE HB Beta is the best method in estimating the percentage of households with a food expenditure share more than 65 percent in the low expenditure group. Regions in the eastern part of East Java Province tend to have higher percentage values, including Sumenep and Lumajang regency, which are categorized as food insecure.

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