Estimating Households that Handle Their Domestic Waste in Not Eco-Friendly Ways in Indonesia: An Application of Small Area Estimation Technique

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Abstract. Waste still becomes a big problem for Indonesia up to now. The Ministry of Environment and Forestry stated that the total volume of waste nationally is 175,000 tons per day or equivalent with 64 million tons per year if using the assumption of waste produced by each person per day is 0.7 kg. According to the 2010 population census, Indonesia’s population is 237 million and this figure is projected to reach around 318 million people in 2045. With a population that continues to grow it will certainly increase the amount of waste generation. Some policy interventions have been set up by the Indonesian government such as the Indonesian President Regulation Number 97/2017 which aims to reduce 30 percent of the country’s waste and to process and manage for at least 70 percent of the country’s waste in order to avoid it from being accumulated in the landfill. Households waste poses a threat to public health and the environment if they are not stored, collected and disposed properly. Data from the 2017 National Socio Economic Survey-Social Resilience Module (SSN17.HANSOS) shows that 68.3 percent of households in Indonesia handle their domestic waste in not eco-friendly ways. Due to lack of availability of reliable data on household waste management at district/city level in Indonesia, this study aims to derive model-based district level estimates of households that handle their domestic waste in not eco-friendly ways by utilizing Small Areas Estimation (SAE) technique.

Keywords: Household waste, not eco-friendly ways, SAE, Indonesia

1. Introduction
Waste is one of the main problems faced by many parties, both government and society, especially in urban areas. This problem does not only occur in Indonesia but in various countries around the world. The Ministry of Environment and Forestry stated that the total volume of waste nationally is 175,000 tons per day or equivalent with 64 million tons per year if using the assumption of waste produced by each person per day is 0.7 kg. According to the 2010 population census, Indonesia’s population is 237 million and this figure is projected to reach around 318 million people in 2045 [1]. The higher the population and their activities, the volume of waste continues to increase. As a result, dealing with waste requires a lot of money and wider landfill. Besides that, waste can endanger health and the environment if they are not stored, collected and disposed properly. [2]
Waste is unwanted residual material after the end of a process carried out by humans (waste is not produced by natural processes). Based on its form, waste can be divided into solid form, liquid, and gas. While based on the source, waste can be grouped into industrial waste, mining waste, and household waste (waste from consumption). [3] Almost all industrial products will become junk at a time, with the amount of waste that is approximately similar to the amount of consumption. Meanwhile, by its nature, waste can be divided into organic waste and inorganic waste. [4]

Waste originating from household consumption is waste produced by humans as users of goods. In other words, consumption waste is waste that is deliberately thrown by humans into the trash. [5] Although the amount of waste in this category is smaller than the waste generated from mining and industrial processes, it still needs to be managed properly to avoid problems later on.

Waste management is carried out in order that waste does not endanger human health and does not pollute to the environment. Waste management is also carried out to obtain benefits for humans. This is done considering that waste is a resource that can be utilized and even has economic values. [6] This consideration is in line with the scarcity of natural resources and the increasingly damage to the environment lately. Waste management is absolutely necessary given the adverse effects, especially for health and the environment. [7] Waste becomes a breeding ground for organisms that cause and carry disease. Waste can also pollute the environment and disturb the environmental balance. Hence not surprisingly, governments in various parts of the world are trying to manage waste properly even though the large cost is needed.

In general, waste management in Indonesia has not been implemented in an integrated way. Waste from various sources, both from households, markets, industries and others, is directly transported to the temporary landfill without going through the process of sorting and processing. From the temporary landfill, the waste is then transported to the landfill and then piled up. Such management ignores the economic value of the waste itself and the benefits of waste as a resource [8].

According to data from the Ministry of Environment and Forestry and the Ministry of Industry, in 2016 [9] the amount of waste generation in Indonesia has reached 64 million tons per year. Some policy interventions have been set up by the Indonesian government such as the Indonesian President Regulation Number 97/2017 which aims to reduce 30 percent of the country’s waste and to process and manage for at least 70 percent of the country’s waste in order to avoid it from being accumulated in the landfill. [11] Households waste poses a threat to public health and the environment if they are not stored, collected and disposed properly. Data from the 2017 National Socio Economic Survey-Social Resilience Module (SSN17.HANSOS) shows that 68.3 percent of households in Indonesia handle their domestic waste in not eco-friendly ways [10].

Data from the SSN17.HANSOS is able to present estimates up to the provincial level in accordance with the design of the designed sample. If it is presented up to the level below the sample design (district / city for example), the estimation results will be methodologically unreliable. This is indicated by the relative value of the standard error (RSE). [11] This is caused by insufficient sample size. Considering that estimation at district level is crucially needed for various programs. Therefore, this study aims to derive model-based district level estimates of households that handle their domestic waste in not eco-friendly ways by utilizing Small Areas Estimation (SAE) technique. [12]

2. Household Waste Management

Proper household waste management can help reduce the negative impact of waste on the environment. Basically, waste management in household can be categorized into eco-friendly ways and not eco-friendly ways. [13] Households are classified as households that handle their domestic waste in eco-friendly ways if they carry out waste management by being transported by officers, disposed of in a temporary shelter, recycled, made into compost/fertilizer, and deposited in a garbage bank. [14] Whereas households are classified as households that handle their domestic waste in not eco-friendly ways if they carry out waste management by dumping it into a river/sewer/ditch, burning it, storing it/burying it, and littering it [15]. Unfortunately, there are still many Indonesian people who do not understand how to handle their domestic waste (See Figure 1).
3. Methodology
The Small Area Estimation (SAE) method is an indirect estimation based on the model by utilizing additional information from other variables as auxiliary variables that are related to the variables of interest. The auxiliary variables can be obtained from the census or administrative records. By borrowing strength of neighboring areas and the auxiliary variables, the SAE method is expected to increase the efficiency of parameter estimates in small area.

In the context of SAE application, [16] were the first researchers who initiated using Empirical Best Linear Unbiased Prediction (EBLUP) approach to estimate log per capita income (PCI) in the US. The Fay-Herriot model is formulated as

$$\hat{\theta}_i = \bar{\beta} x_i^T \beta + z_i u_i + e_i, \quad i = 1, \ldots, m \quad \text{(small area)}$$

where $\hat{\theta}_i$ is a direct estimator for mean area parameter $\theta_i$, $x_i = (x_{i1}, \ldots, x_{iK})^T$ is auxiliary variables, $\beta = (\beta_1, \ldots, \beta_K)^T$ is a vector of regression coefficients, $z_i$ is constat that assumed be known, $u_i$ is a random area-specific effect with $E(u_i) = 0$ and $\text{Var}(u_i) = \sigma_u^2$, $e_i$ is a sampling error which independently and normally distributed with $E(e_i) = 0$ and $\text{Var}(e_i) = \psi_i$.

The Best Linear Unbiased Prediction (BLUP) for $\theta_i$ is formulated as (Rao dan Molina, 2015):

$$\hat{\theta}_i^H = \gamma_i \hat{\theta}_i + (1 - \gamma_i) x_i^T \bar{\beta}, \quad i = 1, \ldots, m \quad \text{(3)}$$

where

$$\bar{\beta} = \bar{\beta} - \sum_{i=1}^m x_i \hat{\theta}_i / \left( \sum_{i=1}^m x_i^2 + \psi_i \right)$$

is the best linear unbiased estimator (BLUE) for $\beta$, [17] and

$$\gamma_i = \sigma_u^2 x_i^2 / \left( \sigma_u^2 x_i^2 + \psi_i \right)$$

is the weight of BLUP estimator.

The BLUP model (3) contains $\sigma_u^2$ that is unknown. We use restricted maximum likelihood (REML) to estimate $\sigma_u^2$. By replacing the $\sigma_u^2$ by REML estimator $\hat{\sigma}_u^2$ yields the empirical best linear unbiased prediction (EBLUP) estimator as follows (see Rao and Molina, 2015):

$$\hat{\theta}_i^H = \bar{\gamma}_i \hat{\theta}_i + (1 - \bar{\gamma}_i) x_i^T \bar{\beta}. \quad \text{(3)}$$

The Mean squared error (MSE) of $\hat{\theta}_i^H$ with assumption that $u_i$ and $e_i$ are normally distributed is [16]:
\[
\text{MSE}(\hat{\theta}_t^H) = g_{11}(\sigma_u^2) + g_{21}(\sigma_u^2) + g_{31}(\sigma_u^2),
\]
(4)

where

\[
g_{11}(\sigma_u^2) = \gamma_i \psi_i.
\]
\[
g_{21}(\sigma_u^2) = (1 - \gamma_i) x_i^2 \sum_{i=1}^{n} x_i z_i^2 / (\sigma_u^2 + \psi_i) \]
\[
g_{31}(\sigma_u^2) = E(\hat{\theta}_i^H - \bar{\theta}_i^H)^2 = \psi_i^2 z_i^4 (\sigma_u^2 + \psi_i)^2 \bar{V}(\sigma_u^2),
\]

where \( \bar{V}(\sigma_u^2) \) is asymptotic variance REML estimator of \( \sigma_u^2 \) that formulated as:

\[
\bar{V}(\sigma_u^2)_{ML} = 2 \left( \sum_{i=1}^{m} z_i^4 / (\sigma_u^2 + \psi_i)^2 \right)^{-1}.
\]

Similarly as Prasad and Rao (1990) in [16], by substituting the REML estimators of \( \sigma_u^2 \), we obtain the estimator of MSE of EBLUP as:

\[
\text{mse}(\hat{\theta}_i^H) = g_{11}(\sigma_u^2) + g_{21}(\sigma_u^2) + 2g_{31}(\sigma_u^2).
\]
(5)

4. Result and Discussion

At national level, the proportion of households that manage waste in eco-friendly way is still relatively high at 63.83 percent (see Figure 2). Then if we look at it from the provincial area, Figure 3 explains that the top three provinces with the proportion of households that manage waste in eco-friendly ways are East Nusa Tenggara (87.51 percent), Gorontalo (86.00 percent), and Central Sulawesi (84.04 percent). While the three provinces with the smallest proportion of households that manage waste in not eco-friendly ways are DKI Jakarta (2.12 percent), Riau Islands (31.80 percent), and East Kalimantan (33.45 percent).

**Figure 2.** Percentage of households according to the Waste Management method, 2017
Figure 3. Percentage of households that handle their domestic waste in not eco-friendly ways by Provinces, 2017

Reliable statistics at district or subdistrict have largely been unable to be met statistically for a variety of reasons, for example due to the unavailability of costs to increase the number of samples. Indirect estimation is an alternative solution that can be done to overcome this problem. Figure 4. shows the comparison of the results of direct estimates and indirect estimates of the percentage of households that
handle their domestic waste in not eco-friendly ways at the district level. The pattern formed between direct estimation and indirect estimation shows the suitability of the pattern.

**Figure 4.** Percentage of households that handle their domestic waste in not eco-friendly ways by Districts in Indonesia, 2017

Even though the pattern is the same, when compared to the direct estimation variance with the indirect estimation variance, the difference is very striking. The indirect estimation variance is relatively smaller than the direct estimation variance (see Figure 5).

**Figure 5.** Comparison of Direct estimation variance and Indirect estimation variance
Figure 6 shows that the indirect estimates are relatively smaller than the RSE direct estimates. This shows that indirect estimation using the EBLUP approach can improve the performance of direct estimates.

![Figure 6](image)

**Figure 6.** RSE of direct estimation and RSE of Indirect estimation

5. **Conclusion**

Often reliable statistics on small areas such as districts and sub-districts are not available. Based on the results of the discussion above, it can be concluded that indirect estimation techniques, i.e. small area estimation (SAE) method can solve this problem and can be used to estimate number of households that handle their domestic waste in not eco-friendly ways at the district level. One of the SAE methods that can be used is the Empirical Best Linear Unbiased Prediction (EBLUP) approach.

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