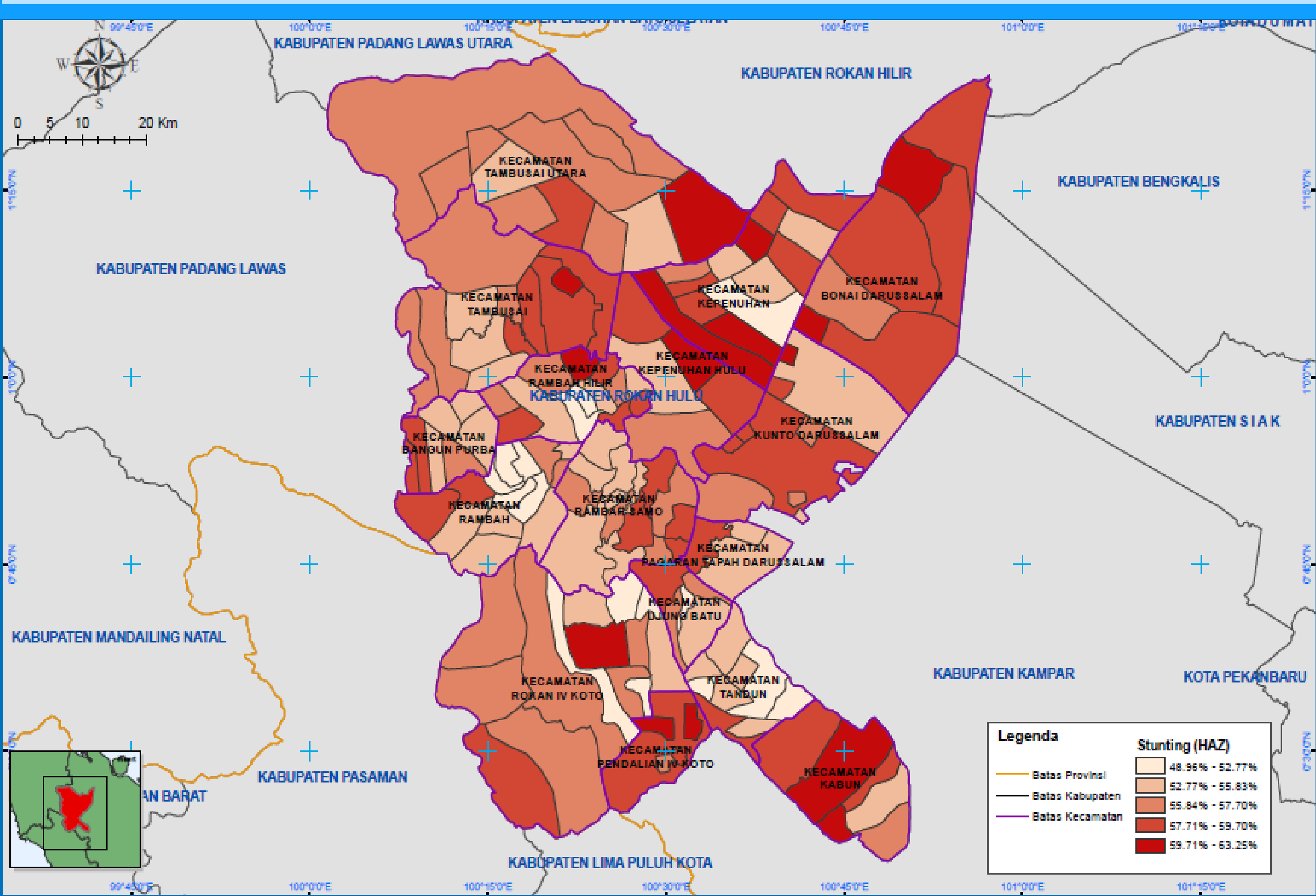
SMERU Research Report

Testing Small Area Estimation (SAE) Method for Generating Nutrition Maps in Indonesia: Rokan Hulu District



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The SMERU Research Institute

October 2019

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Editor: Dhania Putri Sarahtika
Cover photo: Snippet of Rokan Hulu's Stunting Map

The SMERU Research Institute Cataloging-in-Publication Data

Asep Kurniawan
Testing Small Area Estimation (SAE) Method for Generating Nutrition Maps in Indonesia: Rokan Hulu District / Asep Kurniawan; et al. : Editor, Dhania Putri Sarahtika,
Jakarta: Smeru Research Institute, 2019.
57p.; 30 cm.
ISBN 978-623-7492-05-4
ISBN 978-623-7492-04-7 [PDF]

1. stunting; wasting 2. Underweight 3. small area estimation;
I. Title II. Author

DDC'23 363.8

Published by:
The SMERU Research Institute
Jl. Cikini Raya No.10A
Jakarta 10330
Indonesia

First published in October 2019

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ACKNOWLEDGEMENTS

This report has been completed thanks to the support of various parties. For this reason, we express our appreciation and thanks to Mrs. Siti Muchlisoh, M.Si. from Institute of Statistics (STIS), National Team for the Acceleration of Poverty Reduction (TNP2K), and the research team for the assistance that has been given to the authors in collecting data and information needed for the preparation of this report. Our thanks also go to the team from the National Institute of Health Research and Development, Statistics Indonesia (BPS), as well as various ministries and institutions that have provided the quantitative and qualitative data needed to assess the small area estimation (SAE) method in nutritional status estimation of children under five years of age. Without such support, this report would certainly have not been completed. Finally, we express our appreciation and gratitude to all speakers and discussion participants at the dissemination seminar of this report including Tanoto Foundation, other nongovernmental organizations, National Development Planning Agency (Bappenas), and Rokan Hulu District's Regional Development Planning Agency (Bappeda) and Health Agency that have provided inputs to improve this report.

ABSTRACT

Testing Small Area Estimation (SAE) Method for Generating Nutrition Maps in Indonesia: Rokan Hulu District

Asep Kurniawan, Elza Elmira, Maudita Dwi Anbarani, Mayang Rizky, Nurmala Selly Saputri, Ridho Al Izzati, and Ruhmaniyati

This study aimed to test the small area estimation (SAE) method derived from Elbers, Lanjouw, and Lanjouw (ELL) in estimating the nutritional status of children under five years of age at the village and subdistrict levels in Rokan Hulu District. The estimation results were verified quantitatively using an anthropometric census and household-level interviews, and qualitatively using in-depth interviews and village observations. The stunting, underweight, and wasting estimation results at the district level show no significant difference from the benchmark based on the 2013 Riskesdas. The stunting prevalence obtained from the 2019 verification in the villages is relatively 50% lower than the 2013 stunting prevalence. After an estimation model test was carried out, the decrease of the stunting prevalence proved that the SAE model is strong enough to estimate the 2013 prevalence. Such decrease may have been influenced by changes in demographic and socioeconomic characteristics between 2013–2019. Factors affecting the nutritional status are clean water and sanitation, parental educational attainment, household welfare, and villages' commitment to stunting prevention. The maps generated from this study serve as a prototype in expanding nutritional status estimation to all villages in Indonesia as part of the National Strategy in Accelerating Stunting Prevention.

Keywords: small area estimation (SAE), Elbers, Lanjouw, and Lanjouw (ELL), stunting, wasting, underweight, nutritional status maps

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LIST OF ABBREVIATIONS

ATT		average treatment effect on the treated
Balitbangkes	Badan Penelitian dan Pengembangan Kesehatan	National Institute of Health Research and Development
BLUP		best linear unbiased prediction
BPS	Badan Pusat Statistik	Statistics Indonesia
CAPI		computer-assisted personal interviewing
DHS		Demographic and Health Survey
ELL		Elbers, Lanjouw, and Lanjouw
e-PPGBM	Pencatatan Pelaporan Gizi Elektronik Berbasis Masyarakat	Electronic and Community-Based Nutritional Status Reporting
GLS		generalized least squares
HAZ		height-for-age z-score
MSE		mean squared error
OLS		ordinary least squares
Pamsimas	Penyediaan Air Minum dan Sanitasi Berbasis Masyarakat	Community-Based Drinking Water and Sanitation Provision
PHBS	*perilaku hidup bersih dan sehat*	clean and healthy lifestyle
PMT	*pemberian makanan tambahan*	supplemental nutrition program
Podes	Potensi Desa	Village Potential
POmean		mean potential outcome
PSM		propensity score matching
posyandu	*pos pelayanan terpadu*	integrated health service post
puskesmas	*pusat kesehatan masyarakat*	community health center
puskesmas keliling	*pusat kesehatan masyarakat keliling*	mobile community health center
Riskesdas	Riset Kesehatan Dasar	Basic Health Survey
SAE		small area estimation
STBM	*sanitasi total berbasis masyarakat*	community-based total sanitation
Susenas	Survei Sosial-Ekonomi Nasional	National Socioeconomic Survey
TTS	Timor Tengah Selatan	Timor Tengah Selatan
WAZ		weight-for-age z-score
WHO		World Health Organization
WHZ		weight-for-height z-score

EXECUTIVE SUMMARY

Background and Research Methodology

The government's efforts to tackle stunting in Indonesia currently have been held back by several issues. One of the main issues is the limited statistical data available, especially at the subdistrict and village levels. Data availability at these specific administrative levels is important to help determine priority areas and households that should receive stunting prevention program.

In formulating its policies, the government generally relies on survey data. However, the estimation of small areas taken from surveys has the potential to produce a significant standard error since there are very few samples taken. To generate estimation with a high level of accuracy, the small area estimation (SAE) method can be used by borrowing the 'strength' from supplementary data sourced from the regional administrative records or census data. SAE is a method combining survey data and census data to generate more specific statistics of more specific administrative areas such as subdistricts or villages.

The SMERU Research Institute with support of Tanoto Foundation has performed a study on nutritional status estimation using the SAE method in one pilot district: Rokan Hulu. The method used in this study was adopted from the SAE method conducted by Elbers, Lanjouw, and Lanjouw (2003) to estimate poverty and disparity in multiple countries, including Indonesia.

The data used in this study were the 2013 Basic Health Survey (Riskesdas) 2013, 2010 Population Census, and 2011 Village Potential (Podes) data. Using the data, we implemented SAE to obtain village-level nutritional status estimation of children under five years of age.

Estimation Result Analysis

In general, the variables that repeatedly emerge as predictors of nutritional status are parental educational attainment at the individual level, the average education level at the community (village) level, and the types of parents' occupations.

To estimate the nutritional status of children under five years in Rokan Hulu District, a sample of 55,166 children under five years was obtained from the 2010 Population Census. As per the 2010 census, there were 16 subdistricts and 178 villages. The difference between the results of stunting (based on height-for-age z-score or HAZ < -2), wasting (based on weight-for-height z-score or WHZ < -2), and underweight (based on weight-for-age z-score or WAZ < -2) is no more than 5% from the district-level benchmark. The standard error rate for the estimation at the subdistrict level is no more than 15%–20%, while the standard error at the village level can be more than 30%. This was driven by the small sample size used for estimations at some of the villages.

Analysis of Verification Results and Factors Affecting Nutritional Status Change

The prevalence of nutritional status obtained from SAE was then tested using field verification. Considering the budget and time constraints, the verification was limited to three villages. The field verification utilized two approaches, a quantitative approach through anthropometric village census and household surveys and a qualitative approach through in-depth interviews and village observations. The qualitative approach was aimed at obtaining information on factors affecting nutritional status change at the village level in the past five to ten years. Through in-depth interviews and observations, unobserved variables during the census were expected to be obtained through key informants.

When comparing the SAE and verification results, we found that stunting prevalence in the 2013–2019 period in most verification villages experienced a large reduction. The field verification results are, on average, 54%–66% lower than SAE estimation. Meanwhile, field verification results for wasting and underweight prevalence are more consistent with the SAE estimation results. This pattern persists when the results from the villages are aggregated at the district level.

A statistical modelling test was also performed to see the consistency of nutritional status among children under five years old and households with similar characteristics between 2013 and 2019. The test results show that the z-scores between children and household with similar characteristics over the years are not statistically different from each other. Therefore, changes in the demographic and socioeconomic characteristics of children and households at the village level could be one of the sources of the difference between the field verification results and SAE estimation results.

Based on the observed trend, the nutritional status of children under five years in Rokan Hulu has seen improvements during a period spanning from 2013 to 2019. This improvement is primarily seen in the prevalence of stunting, which has seen a quite significant decline exceeding the average village improvement rate of 50%. Various tests performed by the researchers reveal no statistical differences between the estimation and verification results in Rokan Hulu. Differences between the anthropometric and verification results for the period spanning from 2013 to 2019 are caused by the changes in children and community characteristics. Some community characteristics have undergone significant changes which may have contributed to the improvement of nutritional status. The characteristics include household welfare, parental educational attainment, sanitation and environmental condition, access to health service facilities, and commitment of the stakeholders. These findings are consistent in all verification villages in this study.

Several factors which are identified as leading factors affecting nutritional status at the village level are (i) improvement of parental educational attainment; (ii) increase of household welfare; (iii) increase of access to and ownership of decent sanitation and clean water in villages; (iv) stakeholders' commitment, especially the village head's effort in dealing with nutrition issues; and (v) the village being among the national priority villages of stunting or within the coverage of a priority village's community health center (*puskesmas*).

Stunting decline rate tends to be higher in areas where the average years of schooling of mothers is higher than that of the fathers.

In most verification villages in Rokan Hulu District, the increase in average maternal years of schooling is higher than the paternal. This condition indicates that mothers' education is apparently more influential in reducing stunting rate among children under five years. Education would improve their mindset as well as their parenting skills. Higher level of education would develop their knowledge, so that they would be able to improve their parenting skills.

Declining poverty rate in villages and declining stunting condition on children under five years reveal a positive linear relationship.

The greater the poverty reduction in a village, the greater the decrease in stunting rate. Significant reduction in the stunting rate occurred in the villages where poverty declined. In some villages, household welfare improvement was marked by, among other things, the increasing number of working mothers. The improvement of household welfare ultimately encourages an improvement in food intake and, ultimately, the nutritional status of members of the household, especially children under five years.

Increasing number of proper sanitation and clean drinking water in the villages has positive effects to stunting reduction.

Proper sanitation refers to the availability of a squat toilet and a septic tank used for its waste disposal. Meanwhile, clean drinking water refers to the availability of access to bottled water, tap water, river, and protected springs. According to the trend, villages with high stunting decline rates have experienced an increase in the availability of proper home sanitation and access to clean drinking water. The government's support in providing proper toilets and access to clean water, especially through their programs, such as the Community-Based Drinking Water and Sanitation Provision (Pamsimas), has improved the nutritional status of children under five years.

Stronger commitment of relevant stakeholders, especially the village heads, in solving children under five years' nutritional issues.

In general, the village heads allocate a portion of the village budget for the health sector, which includes the health of children under five years. They would raise the incentives for and provide training for integrated health service post (*posyandu*) cadres, support the locals with the provision of proper sanitations, allocate their budget for the supplemental nutrition program (PMT) in the *posyandu* and more.

Conclusion and Recommendations

Estimation model tests show that the SAE estimation model provides good prediction of nutritional status at the village level. The difference between field verification and SAE estimation may be driven by changes in socioeconomic and demographic structures, namely the improvement of parental educational attainment, community welfare, availability of proper sanitation and access to clean water, and the local government's commitment to improving the nutritional status of children under five years.

Such information serves as essential feedback for the central and regional governments in designing the right policies for stunting prevention. Although stunting is a community health issue, the factors affecting its decline are multidimensional. This implies that government institutions of various sectors, such as health and education, need to work together so that efforts to deal with stunting at the national and regional levels are more comprehensive and able to produce desirable outcomes.

These findings suggest that nutritional status estimation replication can be performed in Indonesia. However, there are still some recommendations prior to that. Firstly, the stunting estimation model needs to be employed at a more stable estimation level, such as the national or provincial level. Secondly, it is important to use the most recent survey and census data when conducting SAE estimation since the nutritional status and the characteristics of the community will undergo tremendous changes within a period of five years. In light of that, the most recent census and Riskesdas data are required. The counterfactual method employed by SMERU for Poverty and Livelihood Map of Indonesia 2015 may be used to obtain the new characteristics of the community since new census data are only collected every ten years.

Lastly, the SAE method and its verification that have been implemented in Rokan Hulu District need to be replicated nationally to accelerate national stunting prevention efforts. In addition, census of children under five years old which is already done at *posyandu* regularly could be an alternative to provide the verification data. These efforts need to be sustained through national commitment in accordance with National Stunting Prevention Strategy to accelerate the convergence of programs in priority areas for stunting prevention.

I. INTRODUCTION

1.1 Background

In recent years, stunting[1] has become a great concern for the government, especially due to the fact that Indonesian Basic Health Research (Riskesdas) results revealed increased national prevalence of stunting from 35.5% in 2010 to 37.2% in 2013. As a public health issue, stunting calls for serious actions from various stakeholders. Although the national prevalence of stunting in 2018 went down to 30.8%, the figure is still considered very high as per the standard set out by the World Health Organization (WHO, 2010).

The high rate of stunting in Indonesia has encouraged the government to continuously deal with the issue. However, the government is still lacking in information. As stated by Ravallion and Chao (1989) and Kanbur (1987), policy formulation is often constrained by the limited information needed to determine the target of the program. Policymakers often undergo difficulties when determining the right locations, households, or individuals to be subjected to the program. The statistical data owned by the government are usually limited and do not cover the specific locations such as subdistricts and villages. This needs to be dealt with since the availability of data covering such specific locations is essential to determine the priority areas for relief programs for various socioeconomic problems such as poverty and malnutrition.

In formulating its policies, the government generally relies on survey data. However, the estimation of small areas taken from surveys has the potential to produce a significant standard error since there are very few samples taken. To generate estimation with a high level of accuracy, the small area estimation (SAE) method can be used by borrowing the 'strength' from supplementary data sourced from the regional administrative records or census data. SAE is a method combining survey data and census data to generate more specific statistics of smaller geographical areas such as subdistricts or villages. Several methods that can be used to perform SAE are, for example, mixed models, best linear unbiased predictions (BLUPs), and empirical and hierarchical Bayes (Saei and Chambers, 2003). Several countries such as Ecuador (Hentschel et al., 2000), Vietnam (Minot, 2000), and South Africa (Alderman et al., 2002) have used SAE methods to estimate poverty in small areas. One of the SAE methods frequently used in estimating poverty is the ELL method, which stands for Elbers, Lanjouw, and Lanjouw.

The ELL method was first applied in Ecuador with the use of data covering the households there (Elbers, Lanjouw, and Lanjouw, 2003). The core of this household-level approach is the regression of household welfare parameters—such as consumption-based income or expenses—using a series of common variables found on both survey and census data. Afterward, the parameters are calculated within each household observation in the census in order to generate a more specific proportion of the poor community at a more specific regional level such as subdistricts or villages. The ELL method has been used to estimate the poverty of smaller areas in several countries such as Mexico, Vietnam, and Indonesia. The results are often used as a geographic targeting instrument for policy makers seeking to identify priority areas for poverty alleviation programs (Bedi, Coudouel, and Simler, 2007).

As the need for data grows, the use of ELL method to perform SAE increases in several countries such as Cambodia (Fujii, 2005), Tanzania (Simler, 2006), Dominican Republic (Rogers et al., 2007),

[1]Stunting is characterized by having a shorter body height/length relative to the child's age. It is caused by long-term/chronic nutritional issues (Kementerian Kesehatan, 2019). Its value is expressed in height-for-age z-score (HAZ). A child is defined as stunted when the standard deviation of the HAZ is less than -2 (WHO, 2006).

and Mexico (Rascon-Ramirez and Scott, 2015). These countries used the ELL method to gain the much-needed malnutrition-related data. In Tanzania, Simler utilized health survey and population census data to produce nutritional status figures (2006). In Afghanistan, Akseer et al. (2018) mapped the nutritional status of children and women using the Bayes method of SAE and utilized the data obtained from the National Nutrition Surveys.

The Indonesian government usually relies on the data of demographic and health survey (DHS) or other basic health surveys in mapping malnutrition issues. However, the health statistics data owned by the government are still unable to adequately identify malnutrition issues happening at the lower administrative level. The samples used generally serve as a representative data only for issues at the national level and one level below it—the provincial level, for example. An overview depicting malnutrition at the national and provincial levels can hide the heterogeneity of nutritional status issues at lower administrative levels. The level of malnutrition between districts/cities in one province and between subdistricts/villages in the same district/city may have a considerable difference.

Some researchers who have used the SAE method have tested the validity of the estimation generated by comparing the SAE estimation results and the direct estimate of local surveys. In a SAE calculation for small regions in Norway, Nordbotten (1999) used the comparison of mean squared error (MSE) from the residual to assess the level of SAE accuracy. The comparison between the MSE of the SAE estimation and that of the direct estimate provides an idea of how good the model produced from the SAE method is. A study calculating the per capita expenditure in Banyuwangi District shows that the MSE of SAE is better than the MSE of the direct estimate (Kusuma, Iriawan, and Irhamah, 2017). This means that the SAE method is more reliable than direct surveys when it comes to generating estimations for smaller areas. Another way to assess the accuracy of SAE method is to calculate how many SAE estimation points are located within the 95% confidence interval of the direct estimates. With a high level of accuracy, the SAE method is the answer to the need for a much more affordable health issue and poverty data collection at smaller regions such as villages or subdistricts.

1.2 Objective

This study aimed to estimate the nutritional status—referring to stunting, underweight[2], and wasting[3] prevalence—of children under five at the subdistrict and village levels six priority districts for stunting prevention, namely Rokan Hulu, Lampung Tengah, Tasikmalaya, Pemalang, Jember, and Timor Tengah Selatan (TTS). However, this report focuses on the nutritional status mapping and verification results in Rokan Hulu District.

This study adopted the SAE method conducted by Elbers, Lanjouw, and Lanjouw (2003) to estimate poverty and disparity in multiple countries, including Indonesia. This study also tested the results of the SAE estimation by conducting a direct anthropometric census in several estimation areas at the village level. This verification method will be one of the first verification methods to estimate the nutritional status of children under five years of age.

[2]Underweight is characterized by having a lower weight relative to the child's age. It is caused by long-term deprivation of energy and protein intakes (Kementerian Kesehatan, 2019). Its value is expressed in weight-for-age z-score (WAZ). A child is defined as underweight when the standard deviation of the WAZ is less than -2 (WHO, 2006).

[3]Wasting is characterized by having a lower weight relative to the child's length/height. It is caused by short-term nutritional deprivation or infectious disease. This nutritional problem is considered acute (Kementerian Kesehatan, 2019). Its value is expressed in weight-for-height z-score (WHZ). A child is defined as wasted when the standard deviation of the WHZ is less than -2 (WHO, 2006).

1.3 Report Structure

The first section of the report explains the background and objectives of the study implementation and the data sources used. In the second section, the SAE methodology and the estimation result verification carried out in the studied districts are explored. The third section shows the estimation results of the nutritional status at the subdistrict and village levels using the SAE method. Meanwhile, the fourth section discusses the verification results. The last section of this study presents the conclusion and recommendations of this study.

II. METHODOLOGY

2.1 Study Location

The nutritional status mapping in this study was conducted in Rokan Hulu District, one of the priority districts for stunting in Indonesia. Table 1 shows the nutritional status values in relation to body weight and height in the selected district.

Table 1. Prevalence of Stunting, Wasting, and Underweight in Rokan Hulu District (2013 Riskesdas)

District	Stunting	Wasting	Underweight
Rokan Hulu	59.02%	15.31%	23.56%

Source: 2013 Riskesdas.

2.2 Data Sources

Three sources of data used in the mapping process are as follows: (i) 2013 Riskesdas; (ii) 2010 Population Census; and (iii) 2011 Village Potential (Podes) data. The 2013 Riskesdas data were obtained from the National Institute of Health Research and Development (Balitbangkes). Meanwhile, the Population Census and 2011 Podes data were obtained from Statistics Indonesia (BPS). In the nutrition model estimation, the child weight and height data turned into z-scores are obtained from the 2013 Riskesdas data. The data regarding households and individuals characteristics were obtained from the Indonesian Riskesdas and Population Census data. The data regarding village-level characteristics were obtained from Podes and the average value of the village-level variables from the 2010 Population Census.

Riskesdas is a household survey which is representative of the data up to the district level. The data collection of this research is performed throughout Indonesia. This survey is conducted every three years by collecting the characteristic information of 290,000 households and 1,000,000 individuals. This part of the questionnaire is called the household and individual module. The 2013 Riskesdas data recorded the observation performed on 82,661 infants under 59 months.

Population Census aims to collect demographic, social, and economic data at the individual and household levels. The 2010 Population Census was the sixth census conducted in Indonesia since the independence declaration.

Meanwhile, Podes contains data collected from all villages in Indonesia. The information collected through a village census encompasses village characteristics such as size, population, available infrastructure, labor issues, and village administration. The census questionnaire is filled out by the statistical staff assigned to collect the data. The information is obtained from official village profiles and interviews with village officials. The Podes survey is conducted thrice every ten years. It is usually held prior to and as preparation for the agricultural census, socioeconomic census, and population census. In the 2011 Podes, 77,126 villages were registered.

2.3 ELL Method in Nutritional Status Mapping

This section describes the methodology used to estimate the nutritional status in smaller aggregation areas which, within the context of this study, refer to the village-level areas. This method was adopted from the SAE method employed by Elbers, Lanjouw, and Lanjouw (2003) to estimate poverty and disparity in multiple countries, including Indonesia. By implementing the same method with several adjustments, the nutritional status estimation at a lower aggregation level was conducted by combining survey data and census data (Rizky et al., forthcoming; Negara and Sumarto, forthcoming; Suryahadi et al., 2005; and Suryahadi et al., 2003). This was carried out since the survey data had comprehensive information about the nutritional status but was only representative up to the district level. Meanwhile, the census data contained the demographic data regarding the entire population but did not have the information on nutritional status. By utilizing the characteristics of the population and the community obtained through Riskesdas, the calculation of nutritional status through the census data was able to reach the village level. The nutritional status estimation using the same method had been done previously in Cambodia (Fujii, 2005) and Mexico (Rascon-Ramirez and Scott, 2015).

The estimation process of the nutritional status using the SAE method was quite easy to follow. First, it was necessary to construct a statistical model that could predict the child nutritional status (the child nutritional status was measured by z-score from anthropometric measurements). This estimation was conducted using the same variables between Riskesdas and the Population Census, as well as the location variables found at lower estimation levels, namely village-level variables. Location variables could be obtained from censuses and other village-level statistical data, such as Podes.

There were several stages within the estimation of child nutritional status (z-score) of the census data. The first step was to estimate the beta model:

$$N_{ch} = \boldsymbol{x}_{ch}^{T}\beta + \mathrm{u}_{ch} \qquad (1)$$

The beta model was formulated based on the Riskesdas data. In this model, it is assumed that the child nutritional status in a household (N_{ch}) is influenced by household and individual characteristics and the characteristics of the area (cluster) where the household resides ($\boldsymbol{x}_{ch}$). The *c* index denotes the cluster, while the *h* index denotes the household and individual. In this study, the cluster refers to a village. u_{ch} is an unobservable error that can be broken down into two parts, namely location effects (η_c) and household errors (ϵ_{ch}), which are as follows:

$$\mathrm{u}_{ch} = \eta_c + \epsilon_{ch} \qquad (2)$$

Location effects are characteristics that cannot be observed at the village level but can be estimated, such as the prices of food staples, diversity of education participation among the population and infrastructure that can affect children's health indirectly. Meanwhile, household errors refer to characteristics that cannot be observed at the household level, such as genetics, access to technology for health and productivity improvement, behaviour and attitude, and other non-observable characteristics that can affect anthropometric measurements and child health. Location effects emerged due to some village-level variables of which the information was not available in the survey dataset.

The second step was to calculate the location effects (η_c). As mentioned previously, the η_c estimation for each cluster in the census dataset was not available. Thus, the deviation from η_c

needed to be estimated. The deviation of η_c could be estimated with equation (2) by changing equation (2) into the following:

$$\mathrm{u}_{c.} = \eta_c + \epsilon_{c.} \qquad (3)$$

so that

$$E(\mathrm{u}_{c.}) = \sigma_\eta^2 + Var(\epsilon_{c.}) = \sigma_\eta^2 + \tau_c^2$$

The third stage was to calculate the variance estimation, $Var(\sigma_\eta^2)$. With the assumption that η_c and ϵ_{ch} are distributed normally and independently from one another, Elbers, Lanjouw, and Lanjouw (2003) provided variance estimation of the η_c location effect distribution:

$$\mathrm{var}(\hat{\sigma}_\eta^2) \approx \sum_c \left[a_c^2 \ \mathrm{var}(u_{c.}^2) + b_c^2 \ \mathrm{var}(\hat{\tau}_c^2)\right] \approx \sum_c 2[a_c^2\{(\hat{\sigma}_\eta^2)^2 + (\hat{\tau}_c^2)^2 + 2\hat{\sigma}_\eta^2\hat{\tau}_c^2\} + b_c^2 \frac{(\hat{\tau}_c^2)^2}{n_c - 1}] \quad (4)$$

If there is no η_c location effect, then $\mathrm{u}_{ch} = \epsilon_{ch}$.

The fourth stage was to prepare the residual term to estimate the alpha model. This model was constructed by regressing the transformation of ϵ_{ch} with household characteristics. According to Elbers, Lanjouw, and Lanjouw (2003), the residual term from the ϵ_{ch} household effects can be calculated using the following logistic model equation:

$$\ln \frac{\epsilon_{ch}^2}{A - \epsilon_{ch}^2} = \mathbf{z}_{ch}^T \alpha + r_{ch} \quad (5)$$

In equation (5), A is equivalent to 1.05*max{ϵ_{ch}^2}. The variance estimation for ϵ_{ch} can be calculated using:

$$\hat{\sigma}_{\varepsilon,ch}^2 = \left[\frac{AB}{1+B}\right] + \frac{1}{2}\hat{V}ar(r)\left[\frac{AB(1-B)}{(1+B)^3}\right] \quad (6)$$

The fifth stage was to estimate the generalized least squares (GLS) model. The result of equation (6) indicated that the assumption of ordinary least squares (OLS) being used in equation (1) was not satisfied. Thus, GLS regression was needed. In the GLS model, the variance-covariance matrix is a diagonal block matrix, the diagonal of which is the sum of the variances of location effects and household errors with the following structure:

$$\begin{bmatrix} \sigma_{\eta c} + \sigma_\varepsilon & \sigma_\varepsilon & \sigma_\varepsilon & \sigma_\varepsilon \\ \sigma_\varepsilon & \sigma_{\eta c} + \sigma_\varepsilon & \sigma_\varepsilon & \sigma_\varepsilon \\ \sigma_\varepsilon & \sigma_\varepsilon & \sigma_{\eta c} + \sigma_\varepsilon & \sigma_\varepsilon \\ \sigma_\varepsilon & \sigma_\varepsilon & \sigma_\varepsilon & \sigma_{\eta c} + \sigma_\varepsilon \end{bmatrix} \quad (7)$$

The cov-var matrix as observed in (7) was obtained by using a singular value decomposition to decompose the cov-var matrix in the previous stage, which would be used to form normally distributed random variable vectors.

The last step was bootstrapping. At this stage, the model built based on Riskesdas data was employed to predict the child nutritional status ($\widetilde{N}_{ch}$) of the census data. The simulation model is specified with

$$\widetilde{N}_{ch} = \boldsymbol{x}_{ch}^{T}\widetilde{\beta} + \tilde{\eta}_c + \tilde{\epsilon}_{ch} \qquad (8)$$

where, $\tilde{\beta} \sim N(\hat{\beta}, \hat{\Sigma}_{\beta})$, while $\tilde{\eta}_c$ is a random variable (can be normally distributed or T) with a variance as observed in equation (4), and $\tilde{\epsilon}_{ch}$ is also a random variable (either distributed normally or T) with a variance as observed in equation (6), with $B = exp(\tilde{z}_{ch}^{T}\tilde{\alpha})$ as the beta resulted from the exponential equation (6) and $\tilde{\alpha} \sim N(\hat{\alpha}, \hat{\Sigma}_{\alpha})$ as the alpha perceived to be normally distributed.

As a result of the pilot study of poverty mapping, the standard procedure for using the ELL method in the development of a poverty map was successfully formulated. The same procedure was adopted in this study. The computational procedure used to map the nutritional status of children under five years can be briefly written as follows:

a) data inventorization: making dataset 1, i.e., individual and household variables from the 2013 Riskesdas and additional location variables from the 2011 Podes. Meanwhile, dataset 2 consisted of individual and household variables from the 2010 Census and additional location variables from the 2011 Podes and 2010 Census;
b) estimation of the beta model using dataset 1 (1);
c) calculation of the location effects η_c (2);
d) calculation of the variance estimation $Var(\sigma_{\eta}^{2})$ (4);
e) preparation of the residual term ϵ_{ch} to estimate the alpha model (5);
f) estimation of the GLS model using the cov-var matrix (7);
g) the use of singular value decomposition to decompose the cov-var matrix in the previous stage, which would be used to form normally distributed random variable vectors, then the joint cov-var matrix would be as observed in equation (7); and
h) simulation of dataset 2 using model (8).

The estimation model of nutritional status indicators was determined for each indicator: stunting, wasting, and underweight. The estimation model of each indicator refers to the prevalence of nutritional status for a z-score of <-2 at the district/city level. Although the nutritional status estimation of children under five years could be conducted using the provincial level estimation model, this study used a district/city-level estimation model to document the heterogeneity within the districts/cities. Ideally, each model would at least produce an estimation that had a relative difference of ± 5% from the reference number at the district/city level. If the difference in the aggregation results of estimation at the district/city level had a relative difference that was more than 5% to the district-level reference number from the survey, the model would be adjusted by adding other variables from the census that were statistically equivalent to the survey variables.

2.4 Selection of Estimation Variables

In addition to the level of significance, the selection of independent variables for the purpose of nutritional status indicator estimation also took the results of literature review into account. The selected variables are variables belonging to the the following four characteristics:

a) Parental characteristics

(1) Mother's education (Beal et al., 2018; Fernald et al., 2012; Keino et al., 2014; Mzumara et al., 2018)

(2) Mother's age (Mzumara et al., 2018). Based on the study by Efevbera et al. (2017), early-age pregnancy is not the only cause of stunting. Early-age marriage among women affects stunting through education and economic status.

(3) Mother's occupation (Keino et al., 2014)

(4) Father's education (Beal et al., 2018; Semba et al., 2008; Vollmer et al., 2016)

(5) Father's employment status (Beal et al., 2018)

b) Household characteristics

(1) Welfare status (Beal et al., 2018; Fernald et al., 2012; Keino et al., 2014; Mzumara et al., 2018; Torlesse et al., 2016); this can be concluded from the welfare index made based on asset ownership

(2) Source of potable water (Beal et al., 2018; Mzumara et al., 2018)

(3) Household sanitation (Beal et al., 2018; Keino et al., 2014)

(4) Interaction between sanitation facilities and access to clean water (Torlesse et al., 2016). The risk of stunting will increase threefold in households that consume unclean water and have inadequate sanitation facilities.

c) Child characteristics

(1) Sex (Mzumara et al., 2018; Torlesse et al., 2016)

(2) Age (Beal et al., 2018; Mzumara et al., 2018; Torlesse et al., 2016)

d) Community characteristics

(1) Lack of access to health facilities (Beal et al., 2018)

(2) Rural areas (Beal et al., 2018)

2.5 Verification Method for Estimation Results

Field verification was part of the approach used in the nutritional status mapping of this study. The main objective of the field verification was to compare the estimation results of nutritional status using the SAE method with the real condition of nutritional status in the field. Field verification can be the medium for further inspection to analyze how appropriate the estimation results portray the real condition.

2.5.1 Verification Method: Quantitative

The quantitative method adopted in this study was using a census for data collection on the anthropometric measurements, namely body weight and height/length measurements, of children under five years of age. This census was conducted in three sample villages with different characteristics and different estimation results for Rokan Hulu District. The villages were selected purposively by considering the difference in stunting prevalence values obtained from SAE and by taking into account the standard error, distance between the village and its subdistrict, and the projection of the number of children under five years based on the National Socioeconomic Survey (Susenas) data and 2010 Census data. The three selected villages have different characteristics and stunting prevalence category, i.e., high, medium, and low. In addition, based on the projection results of the population size and number of children under five years in 2018, the selected villages have 200 to 400 children under five years since such numbers are considered to have a statistical predictive power. The enumeration process employed digital questionnaires by utilizing the Android technology. To obtain the digital form, the paper questionnaire was first translated into its digital form using computer-assisted personal interviewing (CAPI) with the assistance of CSPro application which was downloaded for free from the United States Census Bureau.

There were two types of activities related to the enumeration, namely the anthropometric data collection of children under five years and household interviews. To maintain the consistency of verification census data with SAE, the quantitative instrument (questionnaire) was prepared in accordance with the questionnaire materials of 2010 Census and 2013 Riskesdas. The questionnaire used for the children under five years census consisted of four modules, namely Cover Module, Parent Information Module, Main Child Caregiver Information Module, and Home Information Module.

a) Anthropometric census of children under five years

For the collection of anthropometric data, the content of the questionnaire used for the children under five years census was adjusted to the 2013 Riskesdas questionnaire's content. Furthermore, the enumerator only filled out the Child Information Module. The anthropometric census was carried out in integrated health service posts (*posyandu*) in every verification village. The height of children under five years was measured by performing either standing measurement or supine measurement. There were also two ways to measure the weight of children under five years. The first one was by measuring it while the child was standing on the scale, while the second one was by measuring both the child and the mother, a method especially dedicated for children who were still unable to stand by himself/herself. The purpose of the census was to find out the basic information of the children under five years and the main variables constituting the nutritional status, namely birth year, weight, and height. The weight and height measuring instruments used in this census were the Seca digital scale and Seca microtoise/length board.

b) Household interviews

After carrying out the children data collection, the enumerator conducted follow-up interviews with the children’s parents in the respective households. The targeted respondents were the biological mothers of children whose weight and height had been measured. If no biological mother was found, the biological father or primary caregiver of the child or a sibling could be the respondent. The modules filled out during the household enumeration were the Parent Information Module and Home Information Module.

2.5.2 Verification Method: Qualitative

The next steps of the verification process were the implementation of in-depth interviews and village observations. These two steps constituted the study's qualitative approach. The in-depth interviews and observations were conducted simultaneously with the implementation of the census of children under five years. The instrument used in this process was a guide to interviews and observations aimed at digging up information on factors both directly and indirectly related to the nutritional status of children under five years in the villages. Additionally, the changes experienced by these factors in the last five years were also observed. Some important unobserved characteristics of the census of children under five years were expected to be obtained from key informants through this process.

a) In-depth interviews

In-depth interviews were conducted with several key speakers, namely the village heads, village midwives, nutrition officers at the community health center (*puskesmas*), and nutrition officers at the District Health Office. The purpose of the interviews was to obtain information on the context of the village, such as changes in livelihood patterns and changes in the development in the village. The interviews were also aimed at capturing the context within the areas, changes in village infrastructure, availability of programs related to nutrition improvement, commitment of stakeholders, and changes in the level of household welfare. In general, the qualitative approach analyzed the changes happening in villages throughout the last six years (2013–2019). In addition to the in-depth interviews, researchers also collected secondary data regarding weight measurement for children under five years, which were obtained from the monthly measurement data at the village level. The data were expected to be able to support the analysis of the nutritional status of the children in the field.

b) Observations

In addition to the in-depth interviews, the qualitative approach also involved observations. The observations were performed to obtain a comprehensive depiction of the villages' livelihoods through direct observations and transect walks. During the implementation, researchers conducted activities such as random short interviews with villagers and observations on the source of drinking water, sanitation condition, availability of medical services, as well as child caregiving habits and household dietary patterns.

2.6 Analysis Method

2.6.1 Z-score Calculation and Prevalence of Nutritional Status

The first step was to calculate the z-score to determine the nutritional status of children under five years. To generate the z-score, the variables needed were height and weight, sex, and age of children under five years (in months). The age of the children under five years was obtained from the deduction of the day, month, and year of enumeration from the information on the day, month, and year of birth of children under five years. The children included in the observations and analyses were those aged 0 to 59 months or 3 to 1,826 days old. Subsequently, two corrections were made on height data. Height would be reduced by 0.7 cm if the child was older than two years old but measured while in the supine position. Meanwhile, 0.7 cm would be added if the child was younger than two years old but measured while standing. The z-score value was obtained using the following formula:

$$zscore = \frac{x - M}{\sigma}$$

In the formula, x is either the height (TB) or weight (BB), while M represents the median value of height and weight as per the WHO child growth standards tables (2006), whereas σ is the standard deviation of height and weight, which was also taken from the WHO child growth standards tables (2006). The values of M and σ are different for each sex of children under five years and are unique for each age of children under five years (U). The z-score obtained was assumed to be normally distributed. For the height-for-age z-score (HAZ), the minimum value set was -6, while the maximum was 6. As for the weight-for-age z-score (WAZ), the minimum value set was -6, while the maximum was 5. For the weight-for-height z-score (WHZ), the minimum value set was -5, while the maximum was 5. After the z-score value of the nutritional status of each children under five years was generated, the prevalence of the nutritional status of children under five years was able to be calculated based on WHO standards, i.e., children under five years with z-scores below -2 are categorized as deprived of nutrition.

2.6.2 Descriptive Analysis

A descriptive analysis was carried out by describing the indicators related to the parents of children under five years, such as education level and occupation, and indicators related to the condition of sanitation and sources of clean drinking water in the households. The indicators were obtained from the Parent Information Module and Home Information Module of the census of children under five years.

2.6.3 Trend Analysis

In this study, the qualitative approach was performed using the trend analysis method. This analysis aims to study the patterns of events or developments from facts occurring in a certain period or area based on the focused aspects of the study. Each aspect can be identified based on similarities or differences occurring during that certain period or at certain areas. In relation to this study, the analysis was carried out by identifying the development patterns/trends of the nutritional status of children under five years from 2013 to 2019 based on indications of changes observed by studying the factors influencing the changes themselves.

2.6.4 Analysis of Verification Data

A direct comparison between the results of estimation and verification may generate far different data due to changes in the characteristics of the population occurring from 2013 to 2019. Therefore, the second method used in comparing the estimated and verified data integrated the changes in the community characteristics into the SAE simulation. Experiments for the comparison of these data were divided into two scenarios. The first scenario used a reweighting technique on a number of population characteristics, while the second scenario recalculated the prevalence of nutritional status from a number of populations with similar characteristics during the two years of observation (matching). The first scenario was conducted by testing the treatment effect model, while the second scenario was conducted by testing the propensity score matching (PSM).

Borrowing ideas from the treatment effect model, the first scenario balanced the 2019 population characteristics with the 2013 population characteristics used in estimating the prevalence of nutritional status using SAE. This was done because a simple comparison between treated groups, such as the 2019 population of children under five years, and untreated groups, such as the 2013 population of children under five years, may produce bias. Both treated and untreated groups are susceptible to omitted variable bias, namely the bias that occurs due to unobserved differences between the two groups (Ashenfelter, 1978). With the treatment effect model, the estimator produced reweighted data in the hope to obtain balanced data results. The balanced data have a weighted distribution for all of the covariates between the treatment and comparison groups. In other words, the treatment effect model successfully "balanced" the covariates.

Meanwhile, the second scenario used the PSM method. PSM is often carried out in non-experimental studies and aimed at studying the impact of a treatment on selected groups based on the observed characteristic probabilities. In contrast to experimental studies where the selection of the treatment and comparison groups as well as the confirmation of differences between the two are performed in the beginning of the study, PSM is usually conducted using the data derived from observational studies (Austin, 2011). This is done to mimic the process carried out in experimental studies where there are treatment and comparison groups. The difference is that the grouping is conducted after the study has been carried out and based on observable characteristics. In this study, the use of PSM model in the process of comparing the results of estimation and verification was aimed to identify the sources of differences found in the nutritional status of children with the same individual and household characteristics in both data sources.

III. DISTRICT ESTIMATION RESULTS

The nutritional status estimation at the village and subdistrict levels involved 55,166 children under five years of age from the 2010 Population Census as the sample population. Based on the 2010 Population Census data, there are 16 subdistricts and 153 villages in Rokan Hulu District. Estimation results of SAE for stunting (HAZ), underweight (WAZ), and wasting (WHZ) for Rokan Hulu District have less than 5% difference from the benchmark value at the district level. The average standard error for the estimation at the subdistrict level is not more than 15%, while at the village level the standard error can reach more than 30%. This was driven by the small samples for estimation at the village level.

The list of beta and alpha variables used for the SAE of stunting, underweight, and wasting at the subdistrict and village levels in Rokan Hulu District is available in Appendix 1. In general, the variables that repeatedly emerged as predictors of nutritional status were parental educational attainment, both at the individual level and the average at the community (village) level, as well as the occupations of the parents. However, the estimation model varies between the types of nutritional status estimated. All results of the subdistrict-level estimation in Rokan Hulu District are presented in Appendix 2, while the results of the village-level estimation are shown in Appendix 3. The maps displaying the estimation results are in Appendix 4 to Appendix 6.

IV. VERIFICATION RESULTS

4.1 Sample Characteristics in Study Villages

In general, there is no difference in the children's average age, height, or weight among sexes or among verification villages. The total number of children under five years who were successfully enumerated was 639 children with missing observation less than 1% of the total sample; children throwing tantrums or being nowhere to be found during the enumeration process.

Out of all the enumerated samples, less than 1% have outlier z-scores which exceed the minimum and maximum z-score distribution. These observations are not included in the analysis. Table 2 shows that on average, low values of HAZ, WAZ, and WHZ are found in Village B and that the WHZ indicator has better z-scores compared to the other two indicators measuring children's nutritional status.

Table 2. Summary Statistics of Z-scores in Sample Villages

Stunting					
	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Village B	218	-1.27606	1.328135	-4.88	5.4
Village C	253	-0.9634	1.435103	-5.76	5.59
Village A	169	-1.48225	1.332334	-3.82	4.78
Underweight					
	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Village B	218	-1.25945	1.111595	-3.89	2.48
Village C	254	-0.96831	1.265164	-4.27	3.71
Village A	171	-1.37193	0.957954	-3.74	1.84
Wasting					
	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Village B	218	-0.76436	1.118954	-4.47	3.14
Village C	253	-0.62257	1.360837	-4.44	4.97
Village A	170	-0.73318	0.965924	-3.26	1.63

4.2 Nutritional Status Verification Results

In general, the results of stunting status verification based on direct anthropometric measurements are found to be relatively lower, which are at 54%–66%, than the SAE estimation (see Table 3). Meanwhile, the results of verification for wasting and underweight nutritional status have smaller differences compared with the SAE. This pattern is found at the district level which has been aggregated as well as at the village level.

In absolute terms, changes in WAZ between the estimation and verification results are smaller than changes in HAZ. This illustrates that there are fewer nutritional problems related to the children’s weight. On the other hand, WHZ, which is influenced by children's height, also tends to experience major changes. This change can be driven by many factors; mainly the change in the results of measurement of nutritional status between years and the variables used for estimation. Therefore, the estimation and verification results could not be directly compared without prior adjustments. Then, an analysis was carried out to test the estimation model and see the significance of the difference between the estimation and verification results.

Table 3. Comparison between Estimation Results Using 2013 Data and Verification in the 2019 Census Data

District	Stunting		Underweight		Wasting		Village	Stunting		Underweight		Wasting	
	SAE	Census	SAE	Census	SAE	Census		SAE	Census	SAE	Census	SAE	Census
Rokan Hulu	57.2%	28.3%	24.3%	21.6%	15.8%	11.3%	Village B	61.1%	29.5%	30.9%	24.0%	16.9%	12.4%
							Village C	66.5%	20.2%	29.2%	17.5%	16.0%	11.9%
							Village A	54.6%	38.8%	37.8%	24.7%	20.1%	8.9%

4.3 Results of Verification Using Treatment Effect Model

This test observed the prevalence of child nutritional status when each covariate of the datasets of both years was balanced through a covariate reweighting procedure. The procedure was performed on some covariates used to estimate the 2013 nutritional status for children who were given treatment or those belonging to the 2019 dataset. The weight used to balance the covariates of 2013 and 2019 datasets was obtained from the propensity scores of the prevalence of children under five years old in both datasets. Both the raw (before reweighting) and weighted (after reweighting) distribution graph plots reveal that the balancing process performed on each covariate has resulted in a balance between both datasets (see Figure 1).

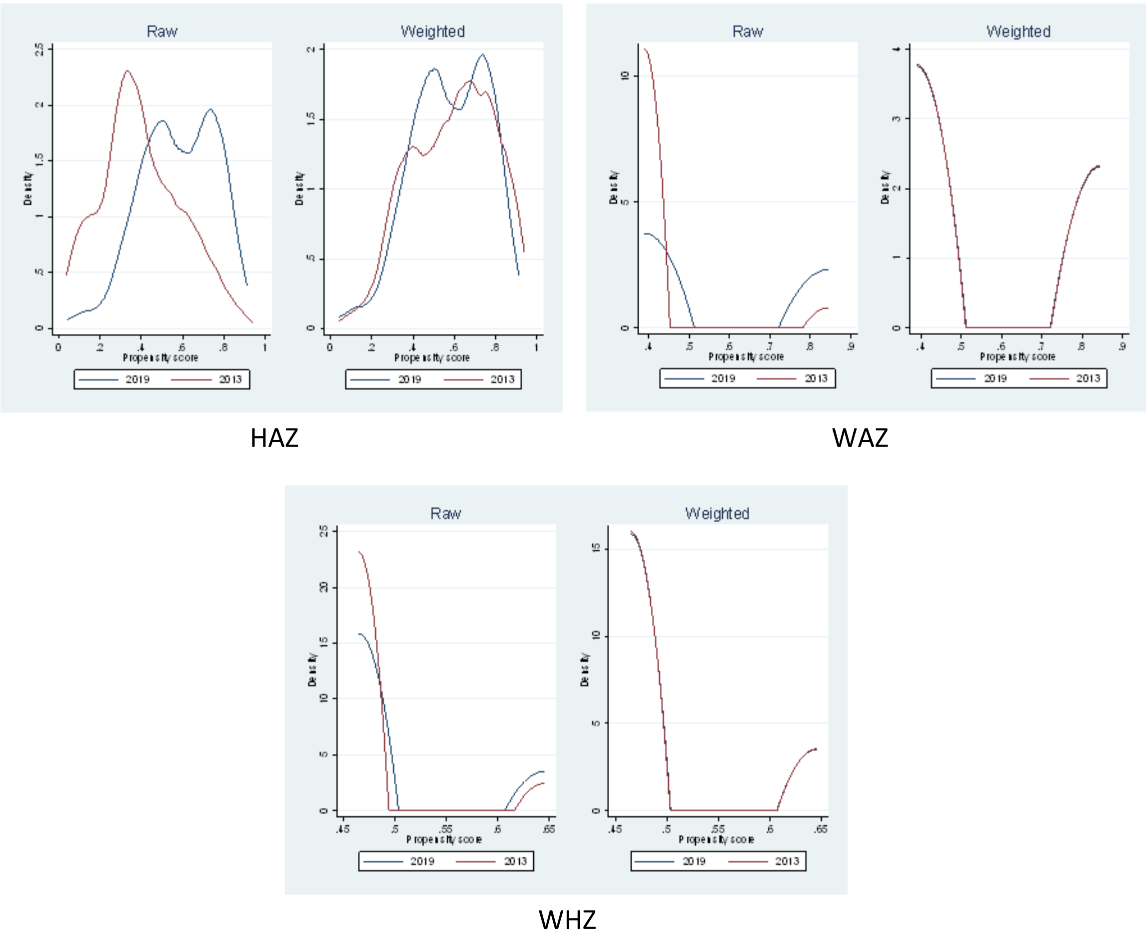

Figure 1. Propensity scores before and after balance reweighting (HAZ, WAZ, and WHZ models)

The mean potential outcome (POmean) and average treatment effect of of the treated (ATT) were able to be obtained when each covariate of both datasets was balanced. POmean refers to the z-score average and the prevalence of nutritional status of children under five years in 2019, provided that the children were not given any treatments or if they appeared in the 2013 dataset (their counterfactual value). Meanwhile, ATT refers to the average of the difference between the z-scores and prevalence in 2019 and their counterfactual values or if the values appear in the 2013 dataset. The comparison between the reweighting result and actual data shows that there are similarities between the actual difference from the 2013 estimation by 2019 direct calculation (Δ) and the ATT (see Appendix 7). The similarities can describe the actual z-score condition and the prevalence of nutritional status in 2013 for the 2019 population of children under five years old. This is also evident in the POmean values of the z-scores and the similar prevalence to the z-scores as well as the prevalence of the 2013 SAE result. Simply put, if the characteristics of children under five years in 2013 and 2019 are balanced, the z-scores and the prevalence of child nutritional status in the 2013 SAE and the 2019 field verification census will result in similar values. Such similarities show that the applied SAE estimation model in Rokan Hulu District has a good predictive power.

4.4 Results of Verification Using Propensity Score Matching (PSM)

Covariate selection for the characteristics-matching process was carried out by ensuring that all outcome-affecting variables, namely the respondents in 2019, were available in 2013. These variables included the age and sex of the children under five years, parental educational attainment, parents’ occupations, household condition, and availability of proper sanitation and clean water supply. The matching method used was the nearest-neighbor method, in which the propensity score of the comparison group was almost the same as the treatment group. After determining the comparison and treatment groups, the desired results from both groups can be directly compared, meaning that the anthropometric results based on estimation and direct measurement can be directly compared.

The anthropometric results from both the treatment and comparison groups generated using PSM show no statistical differences. However, from all of the observations performed during the household census on villages in 2013, only 20% have matches in the 2019 dataset. This indicates an immense change within the village-level community structure since 2013. Apart from the structural change, there are no statistical differences of the anthropometric results between the 2013 SAE estimation and 2019 direct measurement except in Village C (Figure 2). Some quantitatively unobservable factors may be the cause behind the difference. However, no significant statistical differences were found after the z-score observation was carried out on children with the same characteristics in the 2013 and 2019 datasets. This indicates that the applied SAE estimation model has a good predictive power.

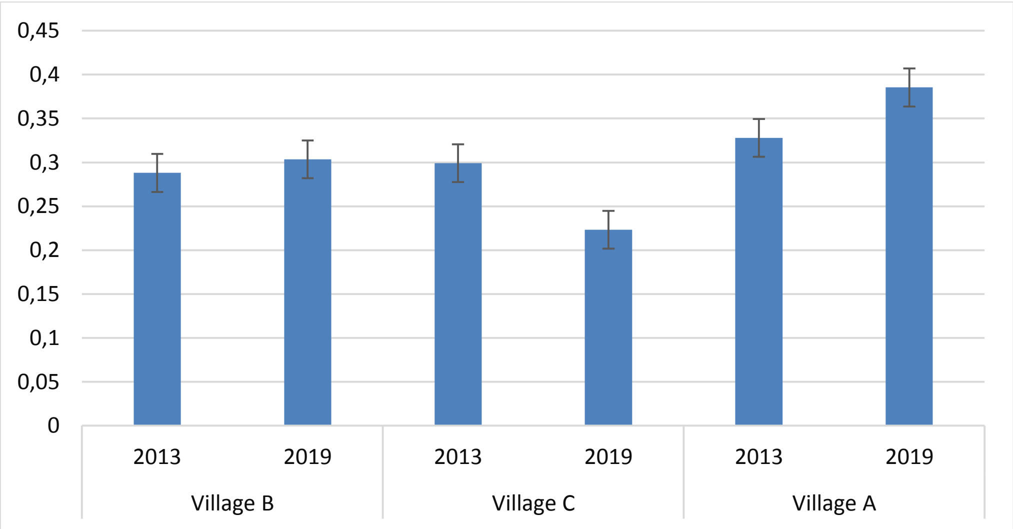

Figure 2. Comparison of stunting prevalence based on 2013 SAE and 2019 Census on children with the same characteristics

After testing the comparison between the anthropometric results performed using SAE estimation and the direct field anthropometric measurement results using PSM method, the next step was to conduct a test on the statistical model used for SAE estimation. In this study, the test was conducted by employing the 2013 estimation model on 2019 community members who had similar covariate characteristics.

The re-estimation, in which the 2019 community characteristics are used, shows consistency when compared to the estimation performed using the 2013 population characteristics (see Figure 3). The consistency of estimations performed using different community characteristics confirms the strength of the prediction model used to estimate the nutritional status in 2013 in Rokan Hulu District.

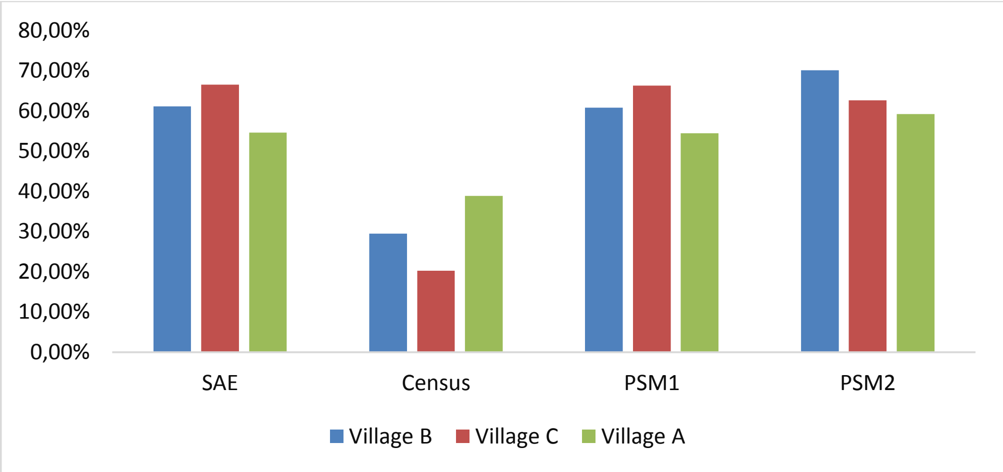

Figure 3. Comparison of stunting prevalence based on 2013 SAE and 2019 Census using PSM samples

4.5 Analysis of Community Changes and Dynamics in Verification Villages

The differences in the conditions of children's nutritional status between the 2013 SAE estimation results and the 2019 field verification census data indicate changes within the community. However, given that the comparison between the estimation and verification results cannot be done directly, as explained in the previous subchapter, it is important to identify any changes within the community since they are also the cause of nutritional status improvement between 2013 and 2019.

Based on the observed change trend, the nutritional status of children under five years in Rokan Hulu's villages has seen improvements during a period spanning from 2013 to 2019. An improvement is primarily seen in the prevalence of stunting, which has seen a quite significant decline exceeding the average village improvement rate of 50%. Various tests performed by the researchers reveal no statistical differences between the estimation results of the three estimation villages and the verification results in Rokan Hulu. The differences between the anthropometric and verification results for the 2013–2019 period are caused by the changes in children and community characteristics. Some community characteristics are found to have undergone significant changes and may have contributed to the nutritional status improvements. The characteristics include household welfare, parental educational attainment, sanitation and environmental condition, access to health care facilities, and commitment of the stakeholders. These findings are consistent in all verification villages in this study.

a) Improvements in parental educational attainment

Within the past decade, the education level of the people in three villages in Rokan Hulu has seen improvements. It is evident in the increasing proportion of university and senior high school graduates. The number of villagers, particularly the mothers, who graduated from senior high school and university sees a significant increase. In 2019, the mothers in the three study villages have surpassed the fathers in terms of education level. The increase in education level is followed by the increase of the average years of schooling in the said villages. The number of fathers who are university and senior high school graduates in the three villages in 2019 is relatively the same, while the number of mothers who graduated from both institutions in Village A is higher (see Figure 4).

The improvement in parental educational attainment is due to increased access to education for the past decade. Elementary and junior high schools, both public and private, are available in each study village. Meanwhile, senior high schools and Islamic senior high schools are available in the two study subdistricts. The proximity to the district capital and the provincial road has also eased access to educational institutions. As evidenced in Village B and Village C, when both parents have a higher education level, the nutritional status improvement of children under five years would even be more visible.

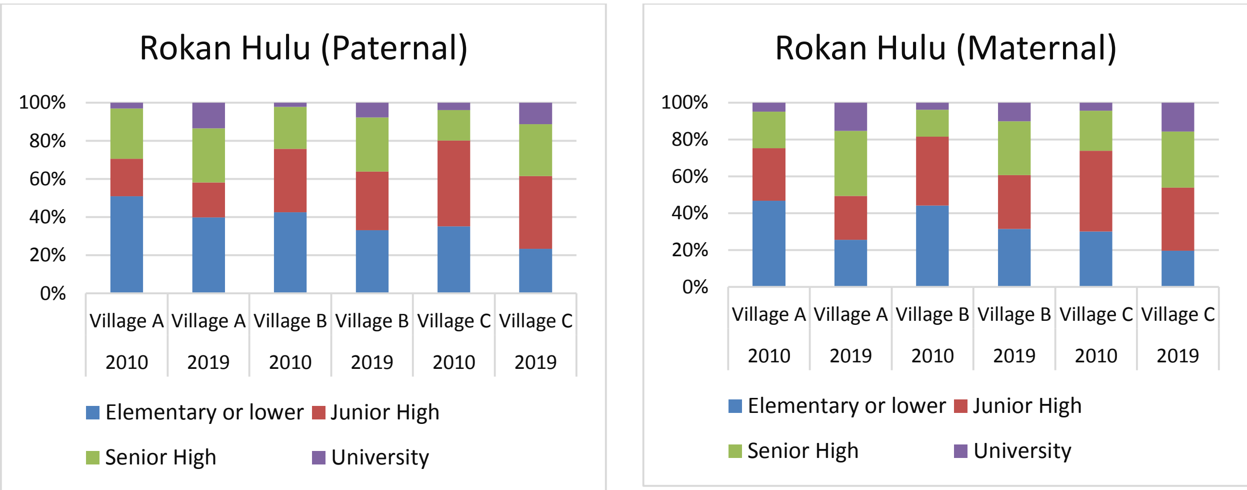

Figure 4. Changes in parental educational attainment in the verification villages in Rokan Hulu District

b) Household welfare improvement

In general, more households in the three villages in Rokan Hulu have been able to improve their financial condition. This is reflected in the declining poverty rate in those villages within the past decade. The highest poverty decline is observed in Village C which also sees declining stunting prevalence. Meanwhile, Village B and Village A rank second and third respectively in terms of poverty decline. The ranking of poverty decline rates in the three villages is consistent with the ranking of stunting decline rates. This indicates that the fluctuation of nutritional status is intertwined with the dynamics of community welfare.

This welfare improvement in the three villages in Rokan Hulu is apparently driven by the parents' coping strategy in which they search for other sources of income, a common practice in the past ten years. This is due to the low prices of palm and rubber, commodities which have been the main livelihood of the locals in the three study villages. For example, the price of rubber this year is between Rp5,000 and Rp6,000 per kilogram, a price far below the price in 2010, which was Rp21,000 per kilogram. Meanwhile, this year's palm price is around Rp1,000–Rp1,200 per kilogram, which is not different from the price in 2010. The fallen prices of crops have made the community earn less than the amount they spend on fertilizers, supplements, etc.

Searching for other sources of income as a coping strategy is highly prevalent in Village B and Village C. According to the interviews with the locals, people choose to freelance to earn more money. In Village C, most people would freelance as laborers in other people's land while still working on their own land. As a result, freelancing while still working on their own land has become a common practice. Meanwhile, many locals in Village B would occasionally go to the town as paid laborers in addition to working on their own land.

In addition to the fathers, Rokan Hulu mothers also practice a coping strategy of earning money from their own job. This reflects their effort to provide more for their families. In 2010, the mothers' role was more of the supportive one. However, the trend has changed in 2019, as more mothers are starting their own businesses, such as running convenient stores or snack stalls.

In the study villages, improving household welfare is followed with improving nutritional status. Better financial condition has enabled the parents to provide sufficient nutritious food for their children. Based on field observations, the children have more varied food options. Besides tofu and *tempe* (fermented soybean), they also have eggs, fish, and chicken meat to meet their protein needs. Furthermore, they also have various types of vegetables (e.g., carrots, broccoli, water spinach, spinach, etc.), which implies that they have sufficient food.

c) Increasing ownership of and access to proper sanitation and clean drinking water facilities in the villages

Within the last ten years, there have been more families owning proper sanitation in the three villages in Rokan Hulu District (see Figure 5). Proper sanitation refers to the availability of squat toilets and a septic tank used for their waste disposal. All three villages see an equal improvement of sanitation facilities, which is nearly twice as much as that of 2010. However, the driving factors among villages are varied.

The main driving factors to increase access to sanitation facilities include the implementation of Community-Based Drinking Water and Sanitation Provision (Pamsimas) program since 2012. One of this program's main activities is its community-based total sanitation (STBM) triggering activity which is meant to foster people's awareness of sanitation and encourage them to abandon their open defecation habit. However, many people in Village A are still reluctant to build proper sanitation facilities in their houses due to financial reasons and because they are already used to defecating in their backyards or the river. This was confirmed by a prominent local figure during an observation, who explained that around 40% of the locals do not have a toilet in their houses.

Though the Pamsimas program had long been introduced in Village B, its implementation had not began until 2018. As it has only been implemented for one year, no drastic improvements regarding the locals' approach to sanitation have been recorded. The real agent of change in the village is the mobile community health center (*puskesmas keliling*), which would visit the village at least 3–4 times a year. Besides providing free medical consultation for the locals, the personnel also promotes a clean and healthy lifestyle (PHBS).

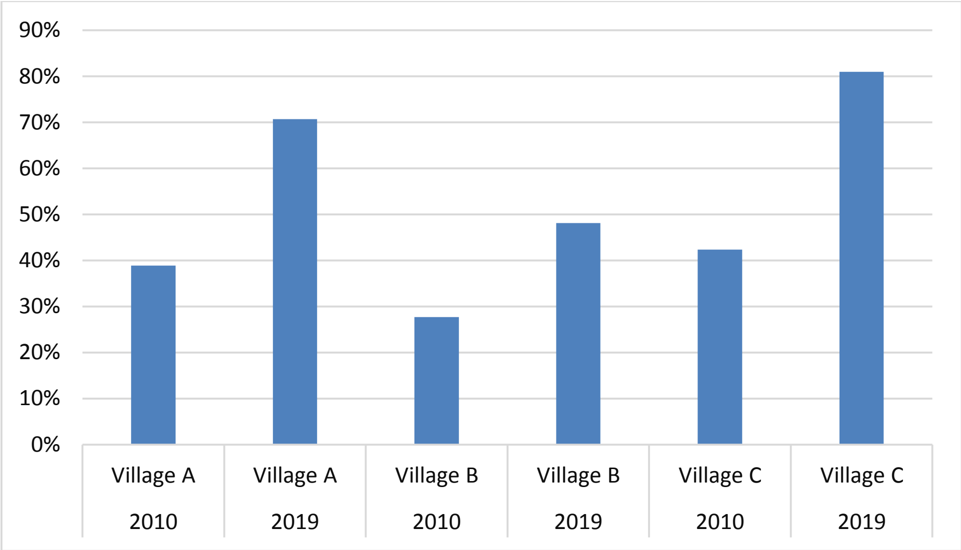

Figure 5. Changes in availability of proper sanitation in the verification villages in Rokan Hulu District

In contrast to the other two villages, the community in Village C is relatively more aware of the importance of having proper home sanitation. According to the village midwife, the locals are more open to issues related to the importance of sanitation for the health of children under five years and therefore are more than willing to build proper toilets and septic tanks. Even without the implementation of special programs such as the Pamsimas, 92% of the families have already owned proper toilets. However, not all of them are equipped with septic tanks because of financial reasons.

In terms of access to clean water within the past decade, Figure 6 shows that the villages in Rokan Hulu have seen improvements, though not really significant. Unfortunately, the trend is not followed by Village B, which sees a slight decline instead. The overall improvement in access to drinking water in the three villages has been due to increasing consumption of bottled water.

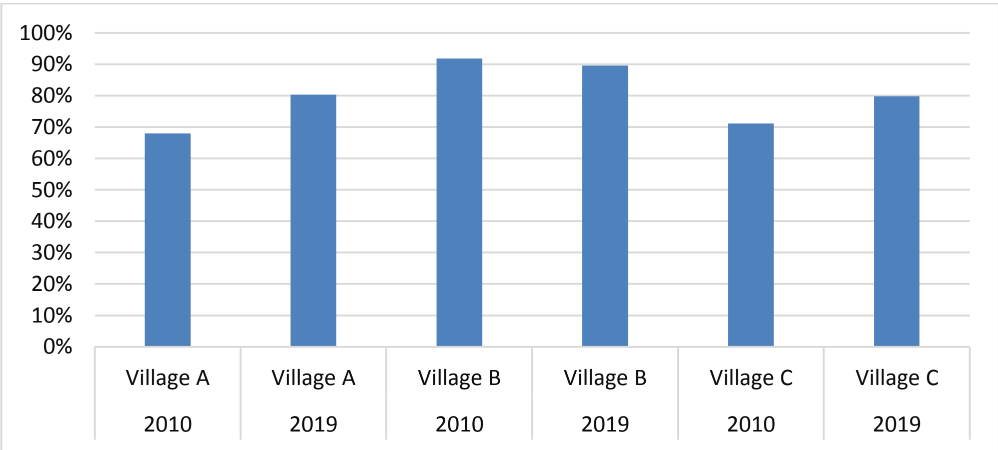

Figure 6. Changes in access to clean drinking water in the verification villages in Rokan Hulu District

The locals tend to consume bottled water because their well water is murky, of which nobody knows the cause. To solve the problem, the locals would filter the water using sand. However, the filtered water is only used for bathing and washing clothes. As for drinking, the majority of them opt for bottled water. The Pamsimas program has not been able to give much contribution because it had not been implemented until 2017. According to the village head, the program funds could only be used to build the main piping infrastructure stretching 3.5 km from the main reservoir to the neighborhood. In 2018, the village budget was used to build the main piping network in one of the hamlets. According to the village head, the access to this network is still limited because the caretakers had not been appointed until early 2019.

d) Stronger commitment of relevant stakeholders, especially the village heads, in solving the nutritional issues of children under five

In nearly all villages that experienced a large decline in stunting, the village heads showed good commitment in relation to the health of children under five. Generally, they have allocated some of the village budget for health-related needs, including the needs of children under five. The activities include increasing the incentives and providing training for *posyandu* cadres, providing sanitation facilities for villagers, and setting aside some budget for the supplemental nutrition program (PMT) for *posyandu*.

e) Being priority villages for national stunting prevention startegy or located within the scope of work of priority villages' *puskesmas*

Concern of the authorities, particularly the local leadership who has direct contact with the people, turns out to be one of the main factors contributing to the declining stunting prevalence in Rokan Hulu. Among the three study village heads, the head of Village C shows the highest attentiveness toward the development of the community health sector. The village head is very concerned about the health of children under five years. It is reflected in his support toward *posyandu* activities. In 2018, he raised the incentive rate for village cadres from Rp25,000 to Rp50,000 per month, and raised it again to Rp100,000 in 2019. He also appointed more cadres in each *posyandu*. What used to be five now became ten cadres. His actions are mainly for the sake of better services, especially because the number of children under five years in his village is relatively higher than in other villages. Furthermore, according to the village midwife, the village head is quite supportive, as she is given enough amount of funds allocated from the village budget to provide PMT and purchase the required equipment for *posyandu*, such as a scale and even a microtoise (height-measuring tape).

The village head's commitment has grown stronger after knowing that one of the neighboring villages in the subdistrict had been categorized as a stunting locus village. On the one hand, the village head admitted that the status would bring support from various sectors to the village. However, he does not want to receive any support given due to such misfortune. "I would rather take preventive actions before it is too late [being categorized as a stunting locus village]," said the village head.

Increasing concern toward the health of children under five is also driven by the encouragement from the head of *puskesmas*. After one of the villages was determined as a stunting locus village, the head of *puskesmas* was the one directly asking the village heads to raise the incentive for *posyandu* cadres.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The high stunting prevalence since 2013 in Indonesia has encouraged the government to take actions against the issue. However, the government is still lacking in information, especially because the only representative stunting data only cover the district level. Trusted for its accuracy, the SAE method is the answer to the need for much more affordable data collection method for health and poverty issues in smaller regions such as villages or subdistricts. Similar studies have been conducted in many countries and SMERU has employed SAE using the ELL method to observe poverty rate at the village level. By adapting the SAE method to analyze poverty data, this study aimed at mapping the nutritional status at the village level in Rokan Hulu District. Additionally, this study also aimed to validate the nutritional status using field verification method and change analysis as the estimation and verification results were not taken in the same period.

In general, the results of stunting status (HAZ) verification in Rokan Hulu District based on the direct anthropometric measurements in 2019 are relatively lower (54%–66%) from the SAE estimation results. Meanwhile, the absolute WAZ difference between the estimation and verification is smaller than that of the HAZ. It implies that nutritional issues relating to children's weight and high volatility of height measurement have decreased. There are many factors encouraging this change, but the main factors are the changes in the annual results of nutritional status measurements and the variables used for estimation. In light of that, both estimation and verification results shall not be directly compared without any proper adjustments.

In this research, several tests were conducted to explain the high stunting status changes throughout the years. The tests were divided into two scenarios. The first one used a reweighting technique on a number of the population's characteristics. Meanwhile, the second scenario recalculated the nutritional status prevalence of some populations belonging to both observation years that shared similar characteristics (matching). The first scenario was conducted using the treatment effect model, while the propensity score matching (PSM) model was used for the second scenario. The test results show that the stunting prevalence resulted from both the estimation and verification on populations with similar characteristics has not experienced any significant statistical changes over the years. Thus, the changes may be caused by the changes in demographic and socioeconomic structures, as well as other unobserved factors.

In general, the significant reduction in stunting rates in Rokan Hulu District is due to improvements in parental educational attainment, community welfare, proportion of residents with proper sanitation and access to clean drinking water, and commitments of local governments to under-five nutrition improvement. The findings serve as essential feedback for the central and regional governments in designing the right policies for stunting prevention. Although stunting is a community health issue, the factors affecting its decline are multidimensional. This implies that government institutions of various sectors, such as health and education, need to work together so that efforts to deal with stunting both at the national and regional levels are more comprehensive and able to produce desirable outcomes.

5.2 Recommendations

The findings in this study show that the mapping of nutritional status of children under five years of age for all villages in Indonesia is possible with some recommendations. First, the modelling of the nutritional status (z-score) needs to be carried out at a higher level of areas than the district, such as at the national or provincial level to obtain a larger sample size and consequently more stable estimation results.

Second, there is a need to examine the consistency of the census of children under five in Rokan Hulu District using 2018 Riskesdas-based SAE. Updated prevalence estimates is crucial in SAE because there is a significant change in the nutritional status related to demographic characteristics during 2013–2018. SAE estimates using Riskesdas 2018 are more relevant with verification results in 2019 due to the smaller gap of observed years compared to when using Riskesdas 2013.

Third, consistency checks of SAE results can be done through the verification using the Electronic and Community-Based Nutritional Status Reporting (e-PPGBM) data. The data are available up to the village level through the implementation of *posyandu*. The 2018 Riskesdas-based SAE estimates are more relevant to be compared with data from e-PPGBM.

Fourth, the census of the nutritional status of children under five years of age done in three villages in Rokan Hulu District needs to be implemented nationally as an effort to support stunting prevention. Data of nutritional status of children under five are available up to district/city level with covering a period of three years. The census for children under five carried out in each session of *posyandu* is the best alternative to provide periodical and real-time data. This effort requires national support and commitment in accordance with the National Strategy for Stunting Prevention to accelerate the convergence of programs in priority areas. The village-level nutritional status maps of children under five are the right references for selecting priority villages in the stunting prevention strategy.

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APPENDICES

APPENDIX 1

Table A1. Model of Estimation for Rokan Hulu District (Beta & Alpha Models)

HAZ					
Beta Model	**Coefficient**	**Standard Error**	**t**	**|Prob|>t**	**Variable Labels**
intercept	-3.93	1.94	-2.03	0.04	Intercept
Paternal education: elementary	-0.54	0.49	-1.09	0.28	Dummy for AYAH_SD=1
Average paternal education at the village level: high school	-1.64	5.72	-0.29	0.77	cv_ayah_slta
Average paternal education at the village level: junior high	1.28	8.91	0.14	0.89	cv_ayah_sltp
Average maternal education at the village level: junior high	-7.89	8.15	-0.97	0.33	cv_ibu_sltp
Average maternal years of schooling in the villages	0.53	0.31	1.69	0.09	cv_ibu_yos
Clean water access	-0.16	0.47	-0.34	0.74	Dummy for DWATER2=1
Sanitation access	0.16	0.66	0.25	0.80	Dummy for FDISPOSAL2=1
Village population	0.00	0.00	-0.82	0.41	pds_pop
Maternal age	0.01	0.04	0.26	0.80	umur_ibu
Alpha Model	**Coefficient**	**Standard Error**	**t**	**|Prob|>t**	**Variable Labels**
intercept	-7.51	2.05	-3.66	0.00	Intercept
_yhat_*_yhat_	1.16	0.67	1.74	0.08	_yhat_*_yhat_
Paternal education elementary*_yhat_	0.39	0.36	1.08	0.28	Dummy for (AYAH_SD)=1*_yhat_
Average paternal education at the village level: high school	12.02	4.31	2.79	0.01	cv_ayah_slta
Average paternal education at the village level: junior high	0.28	8.15	0.03	0.97	cv_ayah_sltp
Average maternal education at the village level: junior high	9.06	11.76	0.77	0.44	cv_ibu_sltp
Average maternal years of schooling in the villages*_yhat_*_yhat_	-0.17	0.11	-1.54	0.13	cv_ibu_yos*_yhat_*_yhat_
Clean water access	0.60	0.43	1.40	0.16	Dummy for (DWATER2)=1
Sanitation access	0.26	0.64	0.41	0.68	Dummy for (FDISPOSAL2)=1
Village population	0.00	0.00	-1.69	0.09	pds_pop
Village population *_yhat_*_yhat_	0.00	0.00	1.25	0.21	pds_pop*_yhat_*_yhat_

WAZ					
Beta Model	**Coefficient**	**Standard Error**	**t**	**|Prob|>t**	**Variable Labels**
intercept	-4.88	4.29	-1.14	0.26	Intercept
Average paternal education at the village level: university	4.68	5.02	0.93	0.35	cv_ayah_pt
Average paternal education at the village level: elementary	2.71	5.14	0.53	0.60	cv_ayah_sd
Average paternal education at the village level: high school	3.90	4.71	0.83	0.41	cv_ayah_slta
Average paternal education at the village level: junior high	2.77	6.85	0.40	0.69	cv_ayah_sltp
Average maternal education at the village level: junior high	1.39	5.35	0.26	0.80	cv_ibu_sltp
Clean water access	0.08	0.28	0.27	0.78	Dummy for DWATER1=1
Distance of village to district office	0.01	0.01	2.01	0.05	pds_distance
Alpha Model	**Coefficient**	**Standard Error**	**t**	**|Prob|>t**	**Variable Labels**
intercept	-3.50	0.24	-14.58	0.00	Intercept
Average paternal education at the village level: university	2.53	2.72	0.93	0.35	cv_ayah_pt

WHZ					
Beta Model	**Coefficient**	**Standard Error**	**t**	**|Prob|>t**	**Variable Labels**
intercept	-1.66	1.48	-1.12	0.27	Intercept
Average maternal education at the village level: junior high	3.00	3.14	0.95	0.34	cv_ibu_sltp
Average maternal years of schooling in the villages	0.04	0.16	0.26	0.80	cv_ibu_yos
Mothers working as entrepreneurs	0.84	2.77	0.30	0.76	Dummy for IBU_BERUSAHA=1
Distance of village to district office	0.02	0.01	2.44	0.02	pds_distance
Alpha Model	**Coefficient**	**Standard Error**	**t**	**|Prob|>t**	**Variable Labels**
intercept	-4.09	0.42	-9.69	0.00	Intercept
_yhat_*_yhat_	-0.55	0.43	-1.28	0.20	_yhat_*_yhat_

APPENDIX 2

Table A2. Estimation of Children's Nutritional Status by Subdistrict in Rokan Hulu District

ID	Subdistrict Name	Number of Children	Prevalence of Nutritional Status					
			WAZ	SE	WHZ	SE	HAZ	SE
1407010	Rokan Iv Koto	2,017	28.9%	6.4%	15.6%	4.3%	38.1%	8.3%
1407011	Pendalian Iv Koto	1,069	19.0%	5.4%	11.2%	4.0%	43.3%	11.1%
1407020	Tandun	2,516	19.7%	4.3%	13.2%	3.3%	41.4%	7.0%
1407021	Kabun	2,679	15.5%	5.2%	11.2%	4.5%	42.7%	7.6%
1407022	Ujung Batu	4,465	23.1%	5.2%	17.0%	4.4%	39.0%	5.3%
1407030	Rambah Samo	2,863	33.8%	5.0%	20.6%	4.7%	38.0%	8.9%
1407040	Rambah	4,516	34.3%	5.3%	24.7%	6.4%	31.1%	8.3%
1407041	Rambah Hilir	3,446	32.8%	4.9%	20.4%	3.9%	42.3%	8.7%
1407042	Bangun Purba	1,718	34.1%	5.7%	18.8%	4.1%	44.5%	13.9%
1407050	Tambusai	7,378	25.3%	4.2%	15.9%	3.2%	41.0%	6.0%
1407051	Tambusai Utara	9,529	19.9%	5.6%	12.4%	3.6%	43.2%	12.6%
1407060	Kepenuhan	2,589	24.7%	4.8%	15.4%	3.2%	43.0%	9.4%
1407061	Kepenuhan Hulu	2,033	27.4%	6.2%	18.0%	3.8%	44.0%	8.8%
1407070	Kunto Darussalam	4,498	19.0%	5.3%	12.5%	3.9%	45.8%	11.3%
1407071	Pagaran Tapah Darussalam	1,390	23.3%	5.8%	15.9%	3.7%	39.8%	6.7%
1407072	Bonai Darussalam	2,460	13.0%	8.7%	10.3%	6.7%	42.1%	9.3%
1407	Rokan Hulu	55,166	24.3%	3.7%	15.8%	2.5%	41.1%	5.9%

[a]SE: Standard Error

APPENDIX 3

Table A3. Estimation of Children's Nutritional Status by Village in Rokan Hulu District

Village ID	Subdistrict	Village	Number of Children	WAZ	SE	WHZ	SE	HAZ	SE
1407010001	Rokan IV Koto	Cipang Kiri Hulu	202	37.3%	14.4%	18.6%	11.7%	49.3%	21.9%
1407010002	Rokan IV Koto	Cipang Kiri Hilir	194	37.9%	22.4%	17.5%	11.4%	44.9%	20.1%
1407010007	Rokan IV Koto	Sikebau Jaya	180	22.7%	7.1%	13.4%	5.9%	59.6%	18.0%
1407010008	Rokan IV Koto	Lubuk Bendahara	186	21.4%	13.5%	13.0%	5.5%	60.2%	23.0%
1407010009	Rokan IV Koto	Lubuk Bendahara Timur	223	22.8%	7.2%	14.7%	6.6%	58.7%	17.0%
1407010010	Rokan IV Koto	Tanjung Medan	69	33.0%	13.4%	19.3%	9.3%	48.4%	29.6%
1407010011	Rokan IV Koto	Rokan	133	24.2%	9.2%	13.3%	7.1%	43.3%	12.2%
1407010012	Rokan IV Koto	Cipang Kanan	121	35.7%	11.9%	17.3%	8.9%	48.8%	30.0%
1407010013	Rokan IV Koto	Rokan Koto Ruang	224	23.8%	10.2%	13.0%	5.6%	55.5%	16.1%
1407010014	Rokan IV Koto	Rokan Timur	122	26.8%	9.0%	15.3%	6.2%	57.8%	14.8%
1407010015	Rokan IV Koto	Tibawan	87	26.3%	12.8%	13.5%	7.2%	52.6%	35.1%
1407010016	Rokan IV Koto	Lubuk Betung	108	29.5%	12.4%	17.1%	7.5%	57.5%	21.9%
1407010017	Rokan IV Koto	Alahan	79	29.0%	13.6%	13.5%	6.0%	57.5%	20.3%
1407010018	Rokan IV Koto	Pemandang	89	45.6%	15.2%	25.2%	14.5%	49.3%	22.5%
1407011001	Pendalian Iv Koto	Pendalian	352	17.3%	6.9%	11.3%	5.6%	60.6%	11.1%
1407011002	Pendalian Iv Koto	Bengkolan Salak	144	16.2%	7.5%	11.2%	5.8%	63.4%	14.3%
1407011003	Pendalian Iv Koto	Suligi	221	21.4%	8.6%	11.9%	5.4%	64.4%	22.1%
1407011004	Pendalian Iv Koto	Air Panas	244	20.5%	7.9%	10.6%	5.4%	60.8%	21.6%
1407011005	Pendalian Iv Koto	Sungai Kandis	108	20.4%	12.1%	11.3%	6.1%	58.9%	20.6%
1407020003	Tandun	Kumain	195	19.4%	6.0%	12.1%	5.5%	60.6%	13.5%
1407020004	Tandun	Bono Tapung	158	19.4%	7.2%	13.4%	5.6%	59.6%	15.4%
1407020005	Tandun	Dayo	283	21.4%	6.8%	13.1%	5.1%	51.9%	11.3%
1407020006	Tandun	Tapung Jaya	232	23.4%	10.1%	13.3%	4.8%	60.3%	16.9%
1407020012	Tandun	Tandun	702	18.0%	6.6%	13.7%	6.4%	54.5%	11.3%
1407020013	Tandun	Puo Raya	271	17.3%	5.7%	12.3%	5.3%	53.1%	14.6%
1407020014	Tandun	Sungai Kuning	252	20.8%	8.1%	12.9%	6.2%	64.2%	13.6%
1407020015	Tandun	Koto Tandun	222	20.9%	8.0%	12.8%	4.6%	55.3%	12.1%
1407020016	Tandun	Tandun Barat	201	20.7%	6.8%	14.1%	6.2%	53.7%	15.7%
1407021001	Kabun	Kabun	1,055	13.0%	6.3%	10.6%	6.0%	61.2%	14.0%
1407021002	Kabun	Aliantan	767	16.4%	7.9%	12.7%	5.4%	54.1%	11.7%
1407021003	Kabun	Koto Ranah	114	18.7%	9.4%	10.6%	6.0%	63.5%	13.9%
1407021004	Kabun	Bencah Kesuma	266	22.0%	7.0%	12.5%	5.3%	56.3%	16.6%
1407021005	Kabun	Batu Langkah Besar	263	15.8%	10.1%	9.4%	6.2%	58.5%	15.4%
1407021006	Kabun	Giti	214	14.6%	7.7%	9.9%	6.6%	58.9%	15.1%

Village ID	Subdistrict	Village	Number of Children	WAZ	SE	WHZ	SE	HAZ	SE
1407022001	Ujung Batu	Ujung Batu	1,795	20.8%	8.4%	18.0%	7.9%	53.7%	13.9%
1407022002	Ujung Batu	Ujung Batu Timur	558	20.8%	6.5%	15.5%	5.0%	55.9%	14.6%
1407022003	Ujung Batu	Ngaso	551	26.1%	6.8%	16.4%	5.2%	59.8%	12.0%
1407022004	Ujung Batu	Suka Damai	707	23.1%	5.1%	14.8%	5.7%	58.7%	10.8%
1407022005	Ujung Batu	Pematang Tebih	854	27.3%	6.5%	18.1%	5.3%	58.7%	11.7%
1407030001	Rambah Samo	Rambah Samo Barat	335	35.6%	10.2%	23.8%	8.9%	54.1%	24.2%
1407030002	Rambah Samo	Marga Mulya	194	40.6%	7.7%	23.1%	9.0%	53.0%	20.9%
1407030003	Rambah Samo	Rambah Samo	228	33.2%	7.8%	20.1%	7.1%	53.2%	11.8%
1407030004	Rambah Samo	Karya Mulya	241	36.7%	10.2%	21.8%	8.2%	58.2%	19.8%
1407030005	Rambah Samo	Rambah Baru	230	32.3%	14.1%	20.4%	7.0%	56.5%	17.6%
1407030006	Rambah Samo	Rambah Utama	256	31.4%	9.0%	18.7%	6.1%	61.5%	20.8%
1407030007	Rambah Samo	Pasir Makmur	93	43.3%	13.0%	23.2%	9.7%	49.3%	34.0%
1407030008	Rambah Samo	Masda Makmur	86	27.6%	10.4%	18.7%	7.7%	56.1%	14.0%
1407030009	Rambah Samo	Langkitin	176	38.2%	9.5%	23.4%	9.0%	47.1%	22.8%
1407030010	Rambah Samo	Lubuk Napal	107	42.8%	11.6%	23.5%	10.4%	52.7%	27.4%
1407030011	Rambah Samo	Sungai Salak	81	36.0%	13.6%	18.4%	6.9%	56.5%	29.3%
1407030012	Rambah Samo	Teluk Aur	329	33.8%	11.5%	21.4%	8.0%	56.1%	16.2%
1407030013	Rambah Samo	Lubuk Bilang	132	40.2%	10.8%	23.2%	10.8%	53.7%	12.7%
1407030014	Rambah Samo	Sungai Kuning	375	21.6%	7.2%	14.1%	5.3%	57.6%	16.2%
1407040002	Rambah	Menaming	267	38.4%	15.0%	21.8%	7.2%	54.1%	21.3%
1407040003	Rambah	Rambah Tengah Hulu	264	39.5%	9.5%	22.1%	7.5%	62.1%	18.6%
1407040004	Rambah	Rambah Tengah Barat	354	36.9%	10.1%	24.9%	8.4%	47.5%	14.1%
1407040005	Rambah	Pasir Pengaraian	550	29.7%	8.0%	23.0%	9.2%	44.1%	13.4%
1407040006	Rambah	Rambah Tengah Utara	375	32.1%	8.0%	25.6%	10.1%	42.5%	13.6%
1407040012	Rambah	Rambah Tengah Hilir	274	37.0%	13.1%	25.9%	8.7%	50.6%	10.7%
1407040013	Rambah	Pasir Baru	86	34.6%	11.2%	24.2%	9.5%	55.2%	16.5%
1407040014	Rambah	Tanjung Belit	162	35.0%	14.8%	21.6%	7.6%	54.1%	19.1%
1407040015	Rambah	Sialang Jaya	131	50.3%	11.4%	29.9%	11.7%	50.9%	15.2%
1407040016	Rambah	Koto Tinggi	704	31.5%	8.9%	24.9%	10.9%	42.1%	19.1%
1407040017	Rambah	Suka Maju	403	34.4%	7.1%	23.5%	7.1%	47.6%	8.8%
1407040018	Rambah	Pematang Berangan	613	33.9%	10.2%	27.9%	11.0%	37.2%	22.9%
1407040019	Rambah	Babussalam	244	30.5%	9.8%	26.0%	10.0%	41.9%	18.6%
1407040020	Rambah	Pasir Maju	89	33.8%	13.9%	20.6%	7.8%	56.1%	22.9%
1407041004	Rambah Hilir	Pasir Jaya	267	27.1%	10.8%	15.3%	6.0%	64.1%	18.7%
1407041005	Rambah Hilir	Pasir Utama	367	33.4%	10.1%	17.9%	5.9%	66.4%	25.0%
1407041006	Rambah Hilir	Rambah Hilir	286	31.0%	10.5%	23.8%	8.3%	45.3%	16.2%
1407041007	Rambah Hilir	Rambah Muda	322	26.9%	9.0%	15.3%	6.5%	67.7%	18.6%
1407041008	Rambah Hilir	Sungai Sitolang	195	33.3%	10.9%	19.6%	6.7%	60.1%	22.0%

Village ID	Subdistrict	Village	Number of Children	WAZ	SE	WHZ	SE	HAZ	SE
1407041009	Rambah Hilir	Lubuk Krapat	156	39.7%	12.8%	23.1%	8.9%	57.8%	28.4%
1407041010	Rambah Hilir	Rambah Hilir Tengah	203	37.8%	15.1%	20.1%	7.2%	54.6%	17.4%
1407041011	Rambah Hilir	Rambah Hilir Timur	168	36.7%	11.9%	17.7%	6.8%	60.3%	16.3%
1407041012	Rambah Hilir	Rambah	816	29.5%	9.8%	20.9%	7.3%	57.9%	10.7%
1407041013	Rambah Hilir	Serombau Indah	184	47.7%	14.5%	25.2%	11.2%	52.0%	21.1%
1407041014	Rambah Hilir	Sungai Dua Indah	100	46.4%	13.4%	27.8%	14.4%	47.2%	19.6%
1407041015	Rambah Hilir	Muara Musu	227	32.1%	10.1%	21.6%	6.9%	50.3%	9.5%
1407041016	Rambah Hilir	Sejati	155	31.0%	9.3%	25.5%	8.5%	48.3%	16.2%
1407042001	Bangun Purba	Bangun Purba	233	30.9%	10.2%	16.9%	6.5%	61.1%	15.8%
1407042002	Bangun Purba	Pasir Agung	204	29.2%	9.5%	16.0%	6.9%	66.5%	18.3%
1407042003	Bangun Purba	Pasir Intan	130	45.3%	18.5%	19.0%	7.1%	57.1%	20.6%
1407042004	Bangun Purba	Rambah Jaya	155	27.9%	12.5%	12.8%	5.7%	69.3%	23.2%
1407042005	Bangun Purba	Bangun Purba Timur Jaya	546	34.1%	9.1%	20.5%	6.5%	61.7%	13.8%
1407042006	Bangun Purba	Bangun Purba Barat	256	35.7%	7.9%	20.1%	7.0%	59.0%	15.0%
1407042007	Bangun Purba	Tangun	194	38.2%	11.5%	22.4%	8.1%	60.4%	17.5%
1407050001	Tambusai	Tambusai Barat	580	21.5%	7.2%	11.9%	4.1%	60.8%	12.0%
1407050002	Tambusai	Sungai Kumango	709	32.6%	8.0%	18.9%	5.7%	61.9%	23.5%
1407050003	Tambusai	Batas	300	24.8%	7.1%	16.4%	6.2%	58.9%	12.4%
1407050004	Tambusai	Tali Kumain	219	20.5%	14.8%	17.8%	7.3%	49.5%	26.5%
1407050005	Tambusai	Tambusai Tengah	816	22.9%	6.6%	16.4%	6.0%	59.0%	12.4%
1407050006	Tambusai	Rantau Panjang	283	28.3%	7.6%	16.0%	6.4%	58.9%	13.3%
1407050007	Tambusai	Sialang Rindang	220	31.2%	9.4%	17.1%	6.8%	63.3%	22.5%
1407050008	Tambusai	Tambusai Timur	503	32.7%	8.9%	18.8%	7.8%	52.1%	15.2%
1407050009	Tambusai	Sukamaju	503	20.5%	9.2%	12.1%	5.4%	67.0%	18.4%
1407050015	Tambusai	Batang Kumu	1,534	22.7%	6.0%	15.6%	5.2%	56.4%	8.7%
1407050016	Tambusai	Tingkok	358	34.7%	10.2%	18.7%	7.1%	55.7%	18.6%
1407050017	Tambusai	Lubuk Soting	1,353	23.1%	8.2%	15.1%	6.2%	53.8%	14.8%
1407050001	Tambusai	Tambusai Barat	580	21.5%	7.2%	11.9%	4.1%	60.8%	12.0%
1407050002	Tambusai	Sungai Kumango	709	32.6%	8.0%	18.9%	5.7%	61.9%	23.5%
1407050003	Tambusai	Batas	300	24.8%	7.1%	16.4%	6.2%	58.9%	12.4%
1407050004	Tambusai	Tali Kumain	219	20.5%	14.8%	17.8%	7.3%	49.5%	26.5%
1407050005	Tambusai	Tambusai Tengah	816	22.9%	6.6%	16.4%	6.0%	59.0%	12.4%
1407050006	Tambusai	Rantau Panjang	283	28.3%	7.6%	16.0%	6.4%	58.9%	13.3%
1407050007	Tambusai	Sialang Rindang	220	31.2%	9.4%	17.1%	6.8%	63.3%	22.5%
1407050008	Tambusai	Tambusai Timur	503	32.7%	8.9%	18.8%	7.8%	52.1%	15.2%
1407050009	Tambusai	Sukamaju	503	20.5%	9.2%	12.1%	5.4%	67.0%	18.4%
1407050015	Tambusai	Batang Kumu	1,534	22.7%	6.0%	15.6%	5.2%	56.4%	8.7%
1407050016	Tambusai	Tingkok	358	34.7%	10.2%	18.7%	7.1%	55.7%	18.6%

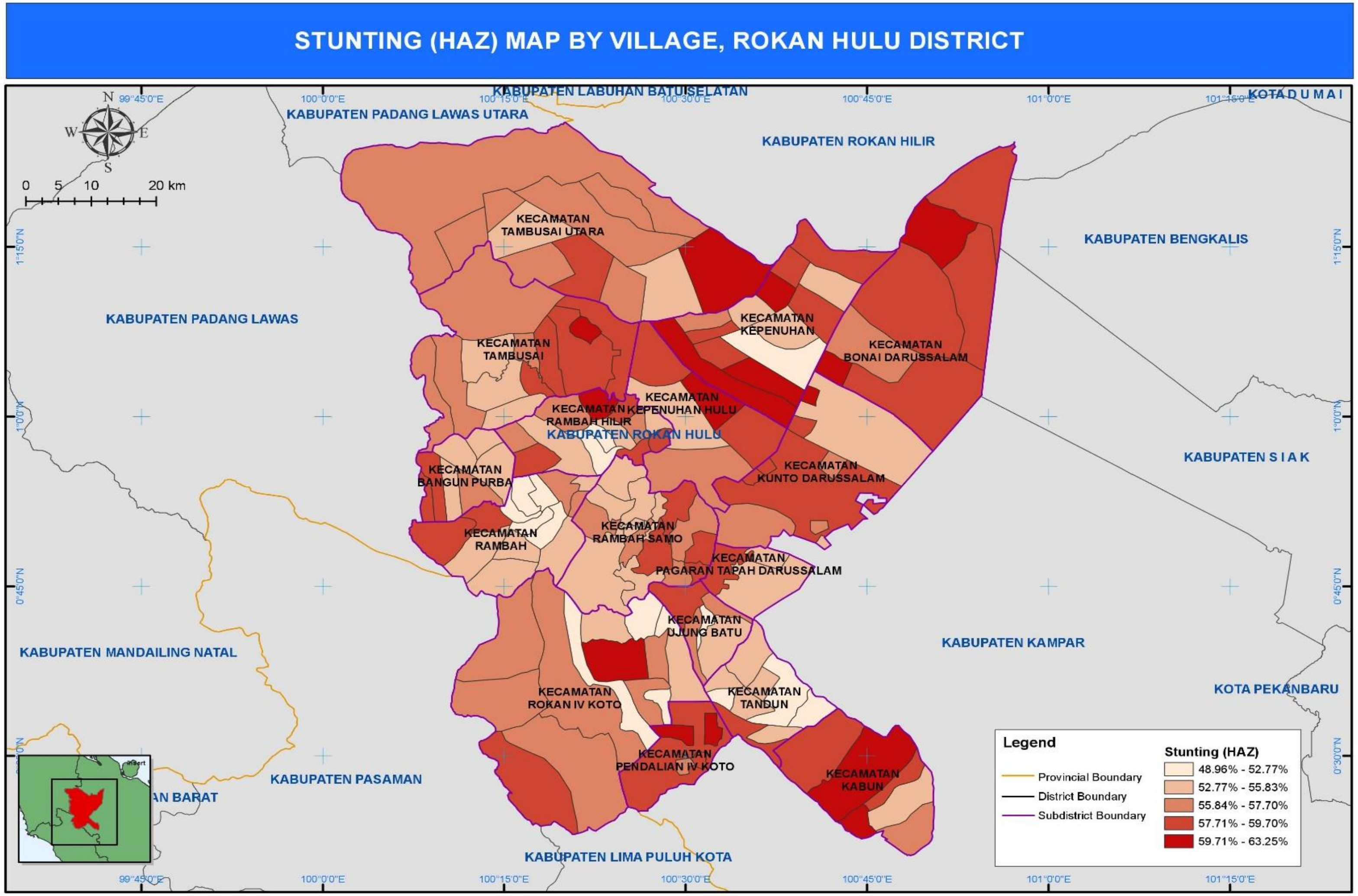
Village ID	Subdistrict	Village	Number of Children	WAZ	SE	WHZ	SE	HAZ	SE
1407050017	Tambusai	Lubuk Soting	1,353	23.1%	8.2%	15.1%	6.2%	53.8%	14.8%
1407051001	Tambusai Utara	Suka Damai	280	20.5%	8.0%	10.8%	5.0%	60.4%	21.3%
1407051002	Tambusai Utara	Mahato Sakti	388	20.8%	7.5%	13.0%	5.6%	61.4%	20.5%
1407051003	Tambusai Utara	Rantau Sakti	510	14.4%	6.1%	10.3%	6.0%	63.4%	15.3%
1407051004	Tambusai Utara	Payung Sekaki	288	22.3%	6.7%	12.5%	5.7%	64.3%	15.9%
1407051005	Tambusai Utara	Pagar Mayang	221	22.4%	8.3%	13.0%	5.3%	60.0%	14.6%
1407051006	Tambusai Utara	Simpang Harapan	166	28.9%	9.4%	19.5%	8.1%	45.9%	22.8%
1407051007	Tambusai Utara	Mekar Jaya	247	25.6%	8.6%	14.4%	5.5%	58.2%	19.6%
1407051008	Tambusai Utara	Bangun Jaya	691	23.6%	5.8%	14.7%	5.1%	57.8%	12.1%
1407051009	Tambusai Utara	Tambusai Utara	3,194	20.9%	7.5%	13.6%	5.6%	54.7%	10.6%
1407051010	Tambusai Utara	Tanjung Medan	435	18.6%	8.1%	10.1%	5.5%	61.1%	17.2%
1407051011	Tambusai Utara	Mahato	3,109	17.7%	7.3%	10.7%	5.3%	63.1%	27.2%
1407060004	Kepenuhan	Kepenuhan Tengah	574	22.8%	6.6%	16.1%	5.7%	51.0%	12.6%
1407060005	Kepenuhan	Kepenuhan Barat	152	31.5%	11.0%	17.1%	7.0%	54.5%	11.5%
1407060006	Kepenuhan	Kepenuhan Raya	203	21.1%	7.8%	12.4%	5.4%	61.1%	17.4%
1407060007	Kepenuhan	Kepenuhan Baru	167	18.5%	8.4%	13.1%	6.5%	61.2%	20.6%
1407060008	Kepenuhan	Upt Sp Iii Koto Tengah/Kepenuhan Makmur	107	26.3%	10.3%	18.3%	7.5%	53.3%	15.3%
1407060009	Kepenuhan	Kepenuhan Timur	252	27.0%	7.5%	15.2%	5.2%	58.6%	10.9%
1407060010	Kepenuhan	Kepenuhan Hilir	129	18.5%	7.4%	12.9%	6.0%	57.9%	16.2%
1407060011	Kepenuhan	Upt Sp Iv Koto Tengah/Kepenuhan Mulya	114	22.9%	7.9%	13.7%	7.2%	59.3%	17.3%
1407060012	Kepenuhan	Upt Sp V Koto Tengah/Kepenuhan Sejati	94	33.1%	13.4%	19.6%	12.6%	53.7%	16.8%
1407060013	Kepenuhan	Ulak Patian	129	50.7%	28.0%	21.1%	13.8%	47.4%	22.4%
1407060016	Kepenuhan	Rantau Binuang Sakti	59	35.6%	19.2%	16.0%	8.2%	53.7%	17.3%
1407060017	Kepenuhan	Kepenuhan Barat Mulya	354	18.0%	6.9%	13.6%	6.1%	62.2%	20.5%
1407060018	Kepenuhan	Kepenuhan Barat Sungai Rokan Jaya	255	23.8%	7.2%	15.1%	6.4%	60.2%	14.7%
1407061001	Kepenuhan Hulu	Kepenuhan Jaya	483	31.9%	11.6%	21.0%	6.7%	62.7%	12.0%
1407061002	Kepenuhan Hulu	Kepenuhan Hulu	238	37.9%	9.7%	20.7%	8.0%	57.6%	27.5%
1407061003	Kepenuhan Hulu	Muara Jaya	525	18.1%	7.2%	13.6%	5.5%	59.4%	13.6%
1407061004	Kepenuhan Hulu	Pekan Tebih	279	34.4%	10.0%	18.3%	7.1%	57.6%	21.1%
1407061005	Kepenuhan Hulu	Kepayang	508	24.2%	7.7%	18.1%	6.1%	58.5%	15.6%
1407070002	Kunto Darussalam	Kota Intan	290	27.8%	12.6%	15.4%	5.9%	55.7%	21.2%
1407070003	Kunto Darussalam	Kota Lama	2,105	18.0%	6.3%	13.1%	5.5%	65.6%	14.4%
1407070006	Kunto Darussalam	Bukit Intan Makmur	133	16.3%	7.4%	11.2%	7.5%	65.8%	19.5%
1407070007	Kunto Darussalam	Muara Intan	110	16.0%	7.2%	11.4%	6.5%	62.7%	19.1%
1407070008	Kunto Darussalam	Bagan Tujuh	110	17.8%	13.4%	14.2%	6.4%	54.3%	21.4%

Village ID	Subdistrict	Village	Number of Children	WAZ	SE	WHZ	SE	HAZ	SE
1407070009	Kunto Darussalam	Intan Jaya	109	14.0%	8.4%	11.7%	6.0%	57.5%	17.2%
1407070010	Kunto Darussalam	Tanah Datar	141	15.4%	6.2%	10.5%	7.3%	64.7%	21.2%
1407070011	Kunto Darussalam	Kota Raya	263	20.2%	10.1%	10.3%	5.1%	60.8%	17.7%
1407070012	Kunto Darussalam	Kota Baru	303	19.3%	6.6%	12.0%	5.8%	58.5%	22.0%
1407070013	Kunto Darussalam	Sungai Kuti	166	23.7%	14.2%	14.4%	6.3%	51.9%	25.6%
1407070014	Kunto Darussalam	Pasir Indah	94	25.6%	12.3%	12.7%	6.2%	60.5%	30.1%
1407070015	Kunto Darussalam	Muara Dilam	514	17.3%	9.1%	11.1%	5.9%	59.6%	12.6%
1407070016	Kunto Darussalam	Pasir Luhur	160	22.6%	13.0%	11.1%	5.6%	52.0%	29.3%
1407070002	Kunto Darussalam	Kota Intan	290	27.8%	12.6%	15.4%	5.9%	55.7%	21.2%
1407070003	Kunto Darussalam	Kota Lama	2,105	18.0%	6.3%	13.1%	5.5%	65.6%	14.4%
1407070006	Kunto Darussalam	Bukit Intan Makmur	133	16.3%	7.4%	11.2%	7.5%	65.8%	19.5%
1407070007	Kunto Darussalam	Muara Intan	110	16.0%	7.2%	11.4%	6.5%	62.7%	19.1%
1407070008	Kunto Darussalam	Bagan Tujuh	110	17.8%	13.4%	14.2%	6.4%	54.3%	21.4%
1407070009	Kunto Darussalam	Intan Jaya	109	14.0%	8.4%	11.7%	6.0%	57.5%	17.2%
1407070010	Kunto Darussalam	Tanah Datar	141	15.4%	6.2%	10.5%	7.3%	64.7%	21.2%
1407070011	Kunto Darussalam	Kota Raya	263	20.2%	10.1%	10.3%	5.1%	60.8%	17.7%
1407070012	Kunto Darussalam	Kota Baru	303	19.3%	6.6%	12.0%	5.8%	58.5%	22.0%
1407070013	Kunto Darussalam	Sungai Kuti	166	23.7%	14.2%	14.4%	6.3%	51.9%	25.6%
1407070014	Kunto Darussalam	Pasir Indah	94	25.6%	12.3%	12.7%	6.2%	60.5%	30.1%
1407070015	Kunto Darussalam	Muara Dilam	514	17.3%	9.1%	11.1%	5.9%	59.6%	12.6%
1407070016	Kunto Darussalam	Pasir Luhur	160	22.6%	13.0%	11.1%	5.6%	52.0%	29.3%
1407071001	Pagaran Tapah Darussalam	Pagaran Tapah	541	25.7%	7.6%	17.5%	5.9%	55.2%	8.9%
1407071002	Pagaran Tapah Darussalam	Kembang Damai	268	23.3%	10.1%	17.7%	6.3%	49.0%	12.0%
1407071003	Pagaran Tapah Darussalam	Rimba Makmur	219	18.6%	7.1%	11.8%	6.3%	62.8%	17.0%
1407071004	Pagaran Tapah Darussalam	Rimba Jaya	215	20.1%	9.8%	13.6%	7.1%	56.7%	14.7%
1407071005	Pagaran Tapah Darussalam	Sangkir Indah	147	25.9%	8.6%	16.4%	6.8%	61.0%	16.7%
1407072001	Bonai Darussalam	Teluk Sono	279	8.0%	7.7%	8.8%	8.0%	52.9%	16.2%
1407072002	Bonai Darussalam	Rawa Makmur	83	32.1%	12.0%	15.8%	6.0%	56.9%	26.8%
1407072003	Bonai Darussalam	Sontang	490	19.1%	9.5%	10.9%	5.7%	57.1%	17.1%
1407072004	Bonai Darussalam	Bonai	351	15.6%	10.9%	10.8%	8.0%	59.1%	24.9%
1407072005	Bonai Darussalam	Pauh	928	7.2%	11.6%	9.8%	10.1%	61.1%	10.8%
1407072006	Bonai Darussalam	Kasang Padang	175	16.1%	8.9%	10.4%	7.0%	57.1%	26.9%
1407072007	Bonai Darussalam	Kasang Mungkal	154	18.5%	13.6%	10.2%	5.6%	56.9%	16.6%

[a]SE: Standard Error

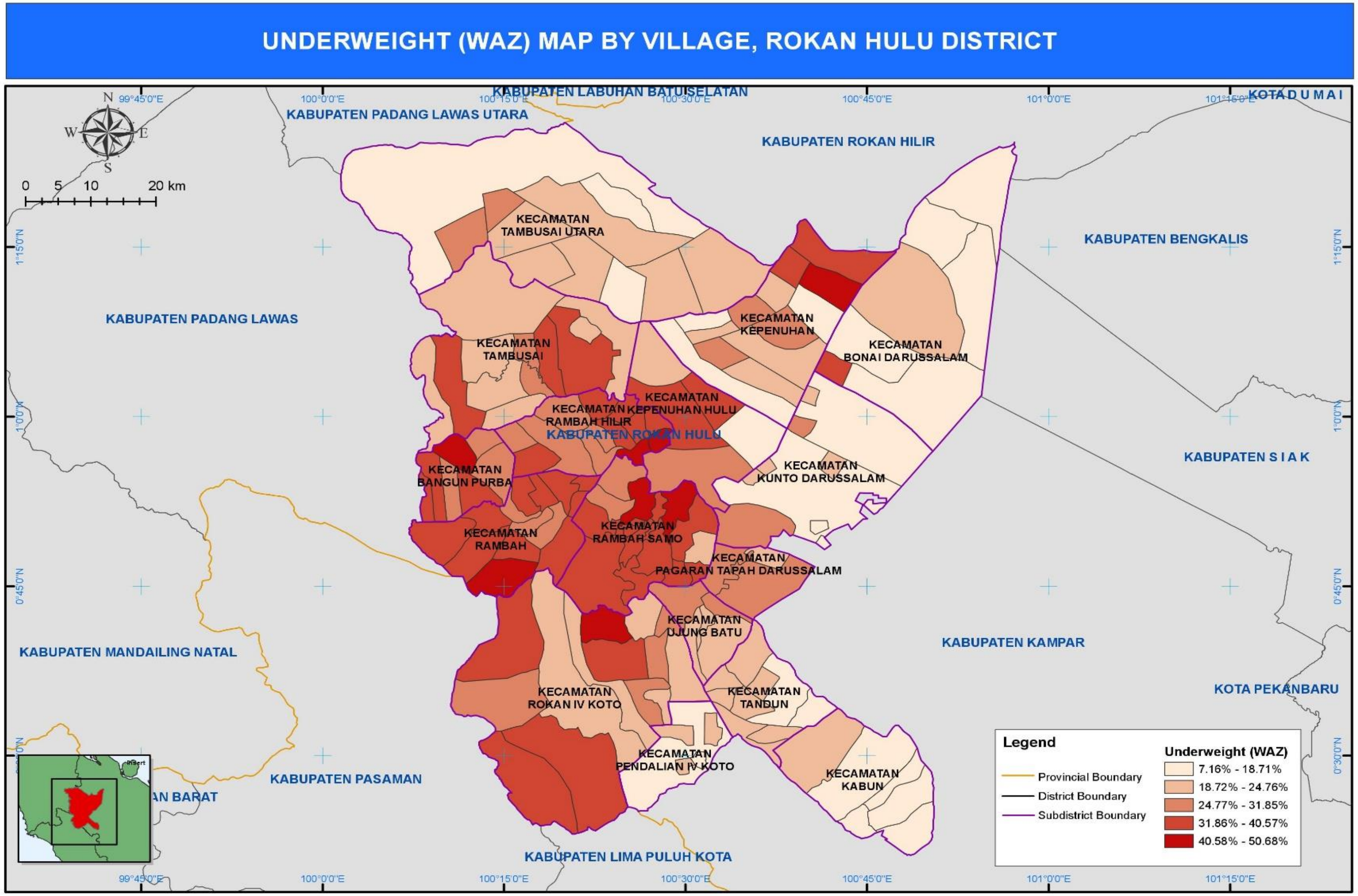
APPENDIX 4

Figure A1. Map of Nutritional Status by Village Based on HAZ (Height/Age) in Rokan Hulu District



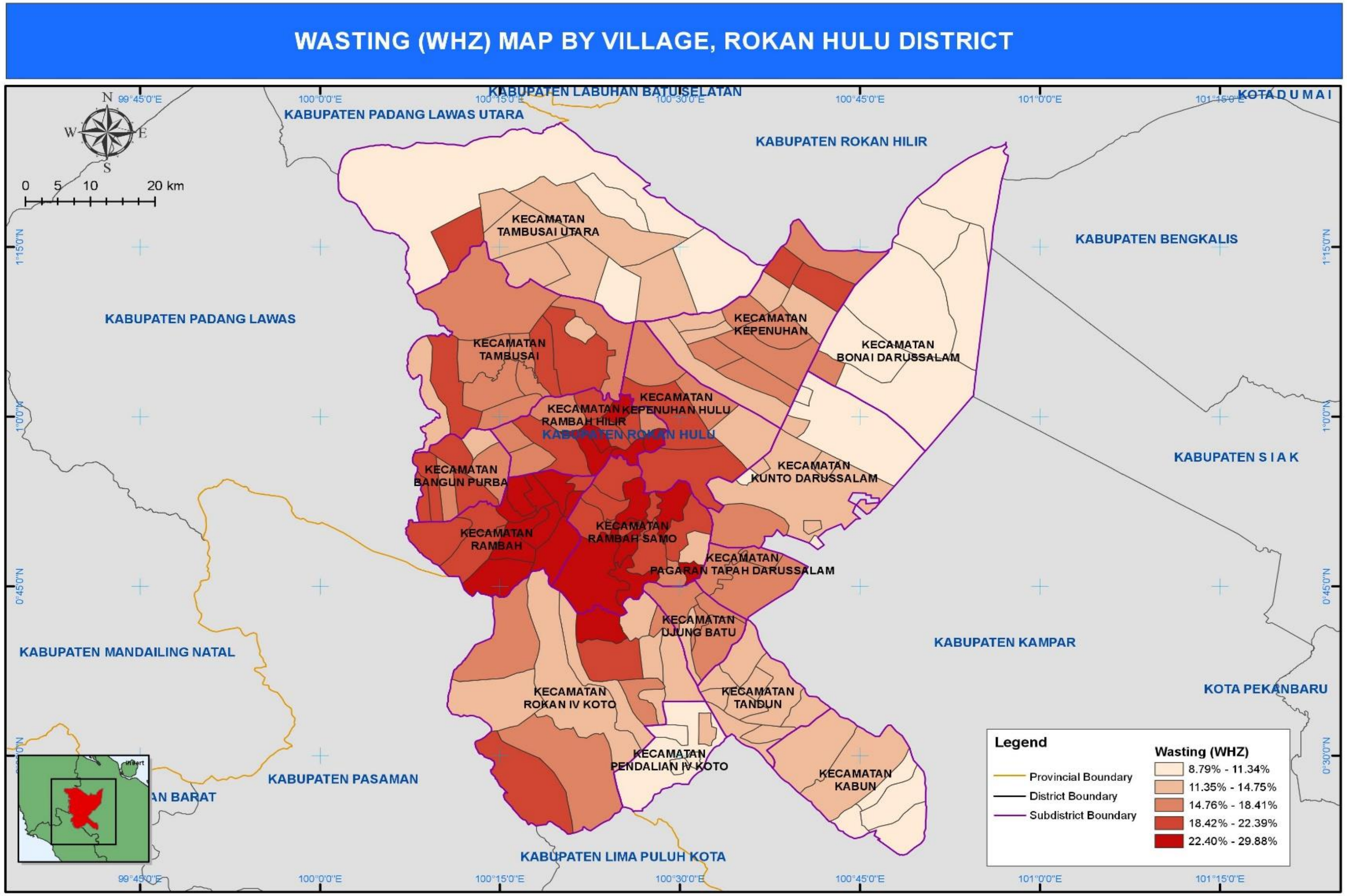
APPENDIX 5

Figure A2. Map of Nutritional Status by Village Based on WAZ (Weight/Age) in Rokan Hulu District



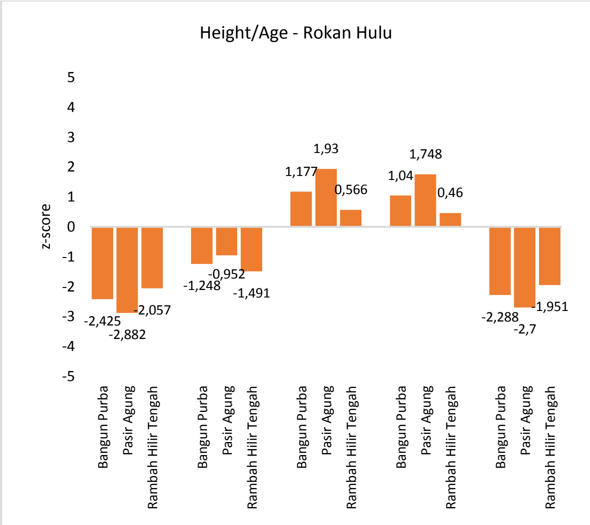
APPENDIX 6

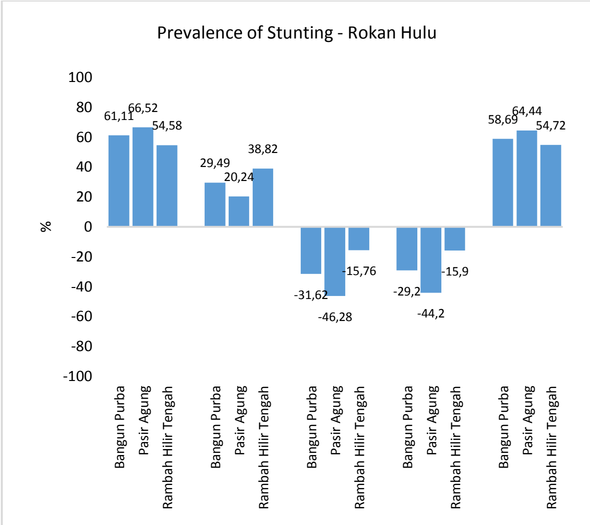
Figure A3. Map of Nutritional Status by Village Based on WHZ (Weight/Height) in Rokan Hulu District

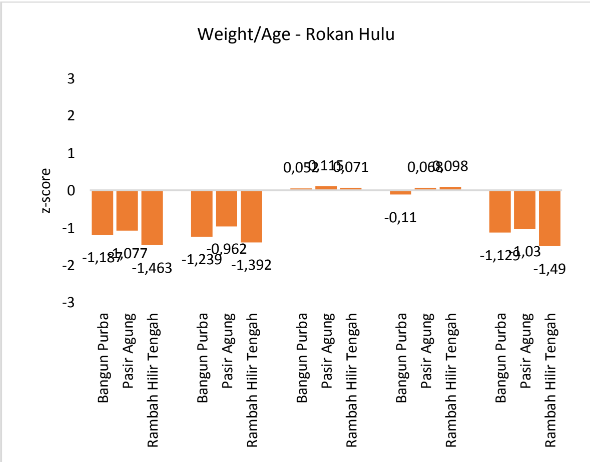


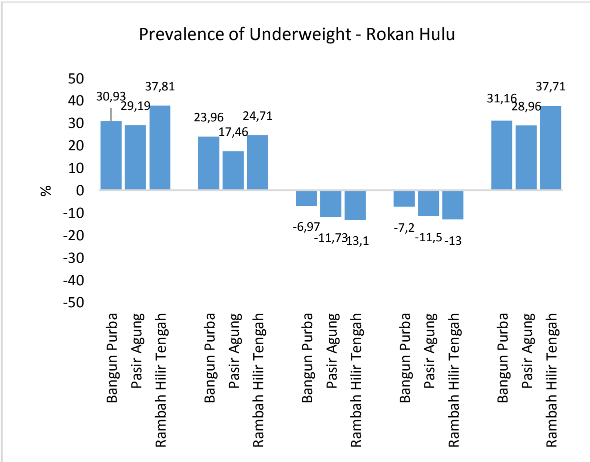
APPENDIX 7

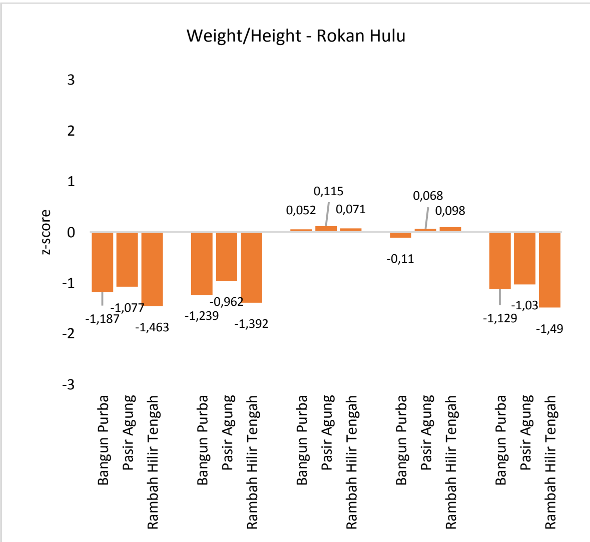
Figure A4. Graphs of Z-scores (Height/Age, Weight/Age, and Weight/Height) and Prevalence of Stunting: 2013 SAE, 2019 Census, Δ, ATT, POmean

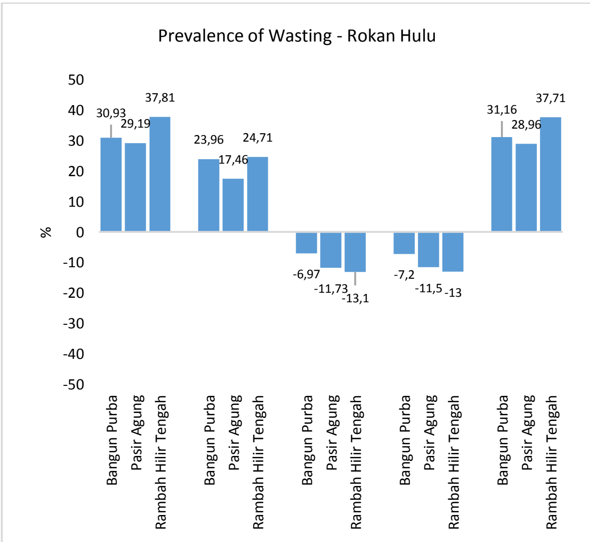












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