JTAM (Jurnal Teori dan Aplikasi Matematika)
http://journal.ummat.ac.id/index.php/jtam
p-ISSN 2597-7512 | e-ISSN 2614-1175
Vol. 9, No. 1, January 2025, pp. 54-67

Mathematical Modeling of Stunting with the Influence of Nutritional Intervention

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Article History:
Received : 25-09-2024
Revised : 16-12-2024
Accepted : 16-12-2024
Online : 01-01-2025

Keywords:
Mathematical Model;
Stunting;
Nutritional Intervention;
Toddlers.

ABSTRACT

The high number of stunting in Central Kalimantan with a prevalence that is still quite far from the WHO threshold, which is 26.9%, requires serious handling from the Central Kalimantan Provincial Government. Through the stunting reduction acceleration program, the government is targeting the prevalence of stunting in Central Kalimantan to decrease to 15.38% by 2024. The purpose of this study was to build a mathematical model to determine the dynamics of stunting events in Central Kalimantan with the influence of nutritional interventions. This model will be used to predict changes in stunting prevalence over time, and evaluate the impact of nutritional interventions on reducing stunting. This is a mixed method research that combines quantitative and qualitative approaches. with a mathematical modelling approach. The research method used in this study is a literature study with data collection techniques through semi-structured interviews with sources from the Health Office, Bappedalitbang and BKKBN which are included in the TPPS of Central Kalimantan, and also the BPS of Central Kalimantan. The data collected includes the prevalence of stunting, types and coverage of nutritional interventions, factors that influence stunting in Central Kalimantan, the nutritional status of toddlers, and indicators of nutritional interventions successstunting prevalence. Model simulation with Python programming shows the effectiveness of the intervention in preventing stunting and helping toddlers at risk of stunting to achieve normal nutritional status. Nutritional interventions have successfully reduced the prevalence of stunting in Central Kalimantan by 3.16% and increased the number of toddlers at risk of stunting who managed to achieve normal nutritional status after receiving nutritional interventions by 7%. It can be concluded that early intervention in toddlers at risk of stunting is very important to prevent stunting, and targeted intervention in stunted toddlers is also needed to accelerate recovery and reduce the overall prevalence of stunting.

Crossref
https://doi.org/10.31764/jtam.v9i1.26817

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A. INTRODUCTION

Stunting is a chronic malnutrition condition that affects the growth and development of children, characterized by a height that is less than the standard for age (WHO). Stunting not only reduces height but also negatively affects a person's quality of life by raising the chance of chronic degenerative diseases, decreasing cognitive and intellectual capacity, losing competitively, and dying. This condition can have long-term negative impacts on the potential of a nation (Suryono et al., 2024; Febriani et al., 2020; Bustami & Ampera, 2020; Yadika et al., 2019). A few internal factors that increase the risk of stunting are low birth weight, insufficient caloric intake, nursing without interruption, persistent diarrhoea, and respiratory tract infections while external factors include filthy water sources, inadequate family finances, low parental education levels, and a high population density in a single household (Febriani et al., 2020; Wicaksono et al., 2021). In Indonesia, stunting is still a serious public health problem, including in Central Kalimantan Province which recorded a stunting prevalence of 26.9% in 2023 (TPPS Kalteng, 2023) exceeds the threshold 20% by WHO (Sadiq et al., 2023). This shows the need for serious handling by the Central Kalimantan Provincial Government.

Several factors influence the high stunting rate in Central Kalimantan, including poor environmental sanitation and lack of access to nutritious food. A study Shinta et al. (2020) showed a significant risk of stunting in communities along the banks of the Kahayan River due to lack of access to nutritious food, unhygienic conditions due to the lack of environmental sanitation facilities for waste management and water disposal, and the habit of people throwing garbage into the river. To address this issue, the Central Kalimantan Provincial Government has set a program to accelerate stunting reduction as one of its priority programs. Through Governor Regulation No. 22 of 2023, the government targets a reduction in stunting prevalence to 15.38% by 2024. Efforts to reduce stunting are carried out by improving the nutritional status and health of toddlers, one of which is through nutritional intervention programs (TPPS Kalteng, 2023).

This study uses mathematical modelling to predict changes in stunting prevalence in Central Kalimantan as a results of nutritional intervention, quantify the impact of nutritional intervention strategies and identify the factors that most influence on the prevalence of stunting in Central Kalimantan. This model can assist the government in planning more effective interventions by predicting the impact of nutritional interventions to prevalence of stunting and identifying key factors that contribute to stunting. The dynamics of a real phenomenon over an extended period of time can be ascertained using mathematical models (Winarni et al., 2024). Several previous studies have developed mathematical models to study the dynamics of stunting (Muh. Isbar Pratama & Lismayani, 2023), (Hasmiati et al., 2024). However, these models may not be fully appropriate to describe the dynamics of stunting in Central Kalimantan. Therefore, this study will develop a new mathematical model that specifically considers the influence of nutritional interventions and local contexts.

B. METHODS

1. Type of Research

This research is a mixed method research that combines quantitative and qualitative approaches. The quantitative approach is used in mathematical modelling and numerical simulation to predict stunting dynamics and evaluate the effectiveness of nutritional interventions. The qualitative approach is used in literature studies and interviews to understand the context of stunting problems in Central Kalimantan and validate the mathematical model developed.

2. Steps of Research

This study was conducted in the following steps:

a. Preliminary Study

The study began with a preliminary study of stunting risk factors, stunting symptoms, stunting prevalence, and government efforts to control stunting in Indonesia, especially in Central Kalimantan. In addition to health literature, researchers also studied several mathematical literatures on epidemiological mathematical modelling for the dynamics of stunting events.

b. Data Collecting

In the next step, researchers collected data through documentation and semi-structured interviews with sources from Dinas Kesehatan, Bappedalitbang, and BKKBN which are included in the TPPS of Central Kalimantan. Another data source is BPS of Central Kalimantan. Data from the internet, websites, and reports were verified and compared with interview results to ensure validity and consistency. The study's data includes the prevalence of stunting, types and coverage of nutritional interventions, factors that influence stunting in Central Kalimantan, the nutritional status of toddlers, and indicators of nutritional interventions success. These data are used to build the mathematical model. For example, the data of the prevalence rate of stunting, the percentage of toddlers at risk of stunting, the percentage of stunted toddlers, the nutritional interventions coverage, and the percentage of toddlers that recover from risk of stunting are used to define compartments, and the transition rate between compartments is used to define parameters that govern the flow of individuals between compartments. The collected data is also used to determine model assumptions, estimate parameter values, validate the model and analyze simulation results.

c. Formulation of Mathematical Model

The next step, we formulated an appropriate mathematical model to describe the dynamics of stunting events in Central Kalimantan by considering the influence of nutritional interventions carried out by the Central Kalimantan government in efforts to control stunting. The mathematical model built by the researcher is a deterministic compartment model. This model was chosen because it can describe the of individuals between groups by considering the factors that influence the transition between these groups. This mathematical model of an ordinary differential equation system (ODE) consisting of four variables, namely: proportion of toddlers at risk of stunting (R), proportion of stunted toddlers (S), proportion of toddlers receiving nutritional intervention (I), and proportion of toddlers who have successfully achieved normal nutritional status after receiving nutritional intervention (N). Each variable is influenced by time. The compartment diagram showing the relationship between variables in this model and its parameters can be seen in Figure 1.

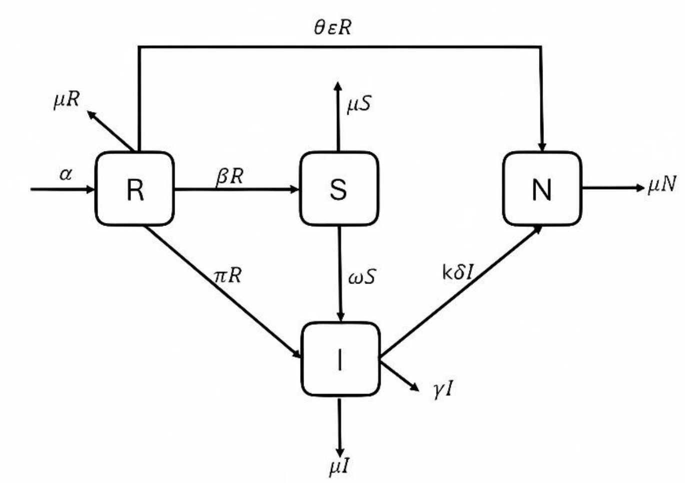

Figure 1. Compartment Diagram of Relationships Between Variables

The parameters used in this study are: α is the rate of entry of new toddlers into the group at risk of stunting (R); β is the rate of transition of toddlers from the group at risk of stunting (R) to the group of toddlers receiving nutritional intervention (I); π is the transition rate of toddlers from group R to group I to receive intervention; μ is infant mortality rate; ω is the transition rate of toddlers from the group of stunted toddlers (S) to the group of toddlers receiving nutritional intervention (I); δ is the rate of recovery of toddlers from the risk of stunting, namely malnutrition; k is proportion of toddlers at risk of stunting who have successfully achieved normal nutritional status after receiving nutritional intervention; ε is the effectiveness of nutritional interventions in preventing toddlers at risk of stunting from becoming stunted; θ is coverage of nutritional interventions in toddlers at risk of stunting; and γ is the rate of toddlers dropping out of the group of toddlers receiving nutritional intervention (I) because they have passed the age limit of 5 years. This mathematical model is built on several assumptions to simplify the complex reality. Here is a Table 1 explaining the model assumptions, related parameters, and their explanations:

Table 1. Model Assumptions and Related Parameters

Assumptions	Parameters	Explanations
Nutritional interventions focus on preventing toddlers at risk of stunting from becoming stunted.	θ, ε	This assumption reflects the focus of the intervention on prevention, so that the coverage (θ) and effectiveness (ε) parameters of the intervention play a greater role in group R.
The number of toddler deaths in each compartment is the same	μ	This assumption simplifies the model by assuming a constant death rate across all groups.
Toddlers who have experienced stunting cannot recover to normal even if they receive nutritional intervention.	k	The available data are toddlers at risk of stunting who succesfully achieved normal nutritional status after receiving nutritional intervention.

Assumptions	Parameters	Explanations
Toddlers who succesfully achieved normal nutritional status after receiving nutritional intervention do not return to being at risk of stunting and experiencing stunting.	−	There is no flow from group N to group R
Stunted toddlers have the same access to interventions as toddlers at risk of stunting.	θ	The same θ value will be used for both groups (R, S) in the model.
Toddlers who receive nutritional interventions are evenly distributed in the age range of 0–5 years.	γ	Toddlers who are over 5 years old are automatically no longer given nutritional intervention even though their nutritional status is not yet normal.
No toddlers entered or left the province during the simulation period.	α, μ	the model only takes into account infant births and deaths using parameters α and μ

The model formulation that corresponds to Figure 1 is:

1) Proportion of toddlers at risk of stunting (R)

The proportion of toddlers at risk of stunting will increase over time along with the increasing number of new toddlers who are at risk of stunting, which can be caused by birth factors at a rate of α. Several other factors that can cause a decrease in the proportion of toddlers at risk of stunting are: the presence of toddlers at risk of stunting who move to group S because they become stunted at a rate of β; some toddlers at risk of stunting receive nutritional intervention and move to group I at a rate of π; the proportion of toddlers at risk of stunting who are successfully prevented from becoming stunted due to nutritional intervention and will move to the normal group (N) with a transition rate of $\theta\varepsilon$, with θ being the level of nutritional intervention, namely how many toddlers at risk of stunting are reached by the nutritional intervention program and ε being the effectiveness of nutritional intervention in preventing stunting in toddlers at risk of stunting; and toddler mortality at a rate of μ. The ordinary differential equation that represents the change in the proportion of toddlers at risk of stunting over time is:

$$\frac{dR}{dt} = \alpha - \beta R - \pi R - \theta\varepsilon R - \mu R \tag{1}$$

2) Proportion of stunted toddlers (S)

The proportion of toddlers experiencing stunting over time will increase with the transition of toddlers at risk of stunting (R) into the group of stunted toddlers (S) at a rate of β and will decrease because the stunted toddlers move to group I to receive nutritional intervention at a rate of ω and there is natural death of stunted toddlers at a rate of μ. The ordinary differential equation that represents the change in the proportion of stunted toddlers over time is:

$$\frac{dS}{dt} = \beta R - \omega S - \mu S \tag{2}$$

3) Proportion of toddlers receiving nutritional intervention (I)
The proportion of toddlers receiving nutritional intervention over time will increase because some toddlers at risk of stunting move to group I to receive nutritional intervention of π and some stunted toddlers move to group I to receive nutritional intervention at a rate of ω. The proportion of toddlers in group I will decrease due to the achieved normal nutritional status of some toddlers who receive nutritional intervention with a proportion of k and a recovery rate of δ, the natural death of stunted toddlers with a death rate of μ, and the exit of toddlers from group I or no longer receiving nutritional intervention because they have passed the age limit of five years with a rate of γ. The ordinary differential equation that represents the change in the proportion of toddlers receiving nutritional intervention (I) over time is:

$$\frac{dI}{dt} = \pi R + \omega S - k\delta I - \mu I - \gamma I \tag{3}$$

4) Proportion of toddlers who have successfully achieved normal nutritional status after receiving nutritional intervention (N)
The proportion of toddlers who have successfully achieved normal nutritional status after receiving nutritional intervention will increase along with the addition of toddlers who receive nutritional interventions and successfully achieved normal nutritional status with a proportion of k and a recovery rate of δ, as well as toddlers at risk of stunting who are successfully prevented from becoming stunted due to nutritional interventions and move to the normal group (N) with a rate of $\theta\varepsilon R$. The decrease in the N group is due to the natural death of toddlers in this group, which is μ. The mathematical equation that represents the change in the proportion of toddlers who have successfully achieved normal nutritional status after receiving nutritional intervention over time is:

$$\frac{dN}{dt} = k\delta I + \theta\varepsilon R - \mu P \tag{4}$$

In full, the stunting control model in toddlers in Central Kalimantan with the influence of nutritional intervention is expressed as a system of ordinary differential equations as in Equation System (5) below:

$$\begin{aligned}
\frac{dR}{dt} &= \alpha - \beta R - \pi R - \theta\varepsilon R - \mu R \\
\frac{dS}{dt} &= \beta R - \omega S - \mu S \\
\frac{dI}{dt} &= \pi R + \omega S - k\delta I - \mu I - \gamma I \\
\frac{dN}{dt} &= k\delta I + \theta\varepsilon R - \mu N
\end{aligned} \tag{5}$$

d. Determination of Equilibrium Point

The behaviour of the system solution (Equation 5) can be known by investigating the behaviour of the system solution that is not dependent on time, which is called the equilibrium point or stationary point (Engida Sado, 2019). Equilibrium point is a state where the system no longer changes over time. By definition, the equilibrium point of the System (5) can be obtained if the system satisfies $\frac{dR}{dt} = 0, \frac{dS}{dt} = 0, \frac{dI}{dt} = 0$ and $\frac{dN}{dt} = 0$, namely:

$$0 = \alpha - (\beta + \pi + \theta\varepsilon + \mu)R \tag{6}$$
$$0 = \beta R - (\omega + \mu)S \tag{7}$$
$$0 = \pi R + \omega S - (k\delta + \mu + \gamma)I \tag{8}$$
$$0 = k\delta I + \theta\varepsilon R - \mu P \tag{9}$$

1) Stunting-Free Equilibrium Point

The stunting-free equilibrium point is a condition when no toddlers experience stunting ($S = 0$). This stunting-free equilibrium point is

$$TE_0 = (R_0, S_0, I_0, N_0) = \left(\frac{\alpha}{\beta + \pi + \mu + \theta\varepsilon}, 0, \frac{\pi\alpha}{(\beta + \pi + \mu + \theta\varepsilon)(k\delta + \mu + \gamma)}, \frac{k\delta\pi\alpha + \theta\varepsilon\alpha(k\delta + \mu + \gamma)}{(\mu)(\beta + \pi + \mu + \theta\varepsilon)(k\delta + \mu + \gamma)}\right)$$

2) Stunting Equilibrium Point

The equilibrium point of stunting is a condition where there are toddlers who experience stunting, in other words, $S \neq 0$. The system of equations (5) has a stunting equilibrium point:

$$TE^* = (R^*, S^*, I^*, N^*) = \left(\frac{\alpha}{\beta+\pi+\mu+\theta\varepsilon}, \frac{\beta\alpha}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)}, \frac{\pi\alpha(\omega+\mu)+\omega\beta\alpha}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)(k\delta+\mu+\gamma)}, \frac{k\delta\pi\alpha(\omega+\mu)+k\delta\omega\beta\alpha+(\theta\varepsilon\alpha)(\omega+\mu)(k\delta+\mu+\gamma)}{(\mu)(\beta+\pi+\mu+\theta\varepsilon)(k\delta+\mu+\gamma)(\omega+\mu)}\right)$$

e. Stability Analysis of Stunting Equilibrium Point

The next step was to determine the stability of the equilibrium by looking at the eigenvalues of the Jacobian matrix obtained. In this study, a stability analysis was carried out on the equilibrium point of stunting. Consider the System of Equations (5), for example: $f_1 = \frac{dR}{dt} = \alpha - (\beta + \pi + \theta\varepsilon + \mu)R$, $f_2 = \frac{dS}{dt} = \beta R - (\omega + \mu)S$, $f_3 = \frac{dI}{dt} = \pi R + \omega S - (k\delta + \mu + \gamma)I$, dan $f_4 = \frac{dP}{dt} = k\delta I + \theta\varepsilon R - \mu N$. The Jacobian matrix is determined first where its elements are the results of partial derivatives of each function with respect to the variables in the model. The Jacobian Matrix for System of Equations (5) is:

$$J_f = \begin{bmatrix} -(\beta + \pi + \mu + \theta\varepsilon) & 0 & 0 & 0 \\ \beta & -(\omega + \mu) & 0 & 0 \\ \pi & \omega & -(k\delta + \mu + \gamma) & 0 \\ \theta\varepsilon & 0 & k\delta & -\mu \end{bmatrix}$$

f. The Jacobian matrix is used to analyse the stability of equilibrium point by looking at its eigenvalues. If all of the real parts of the eigen values are negative, the equilibrium point is locally asymptotically stable, but if there is one positive real part then the equilibrium point is unstable. Numerical Simulations are performed to determine the rationality of the model's interpretation (Fahcruddin et al., 2023). The Runge-Kutta method of Order 5(4) was utilised in conjunction with Python programming to determine the numerical solution of the stunting control model (5) that was formulated in this work. Only a tiny portion of the parameter values were the author's assumptions based on references; the majority of the parameter values were derived from the estimation results using calculations based on available data from the most of the parameter values were obtained from estimation results using calculations based on data available from the Health Office, Bappedalitbang, BKKBN, and BPS of Central Kalimantan Province. Table 2 displays the parameter values for model (5) as follows:

Table 2. Parameters on the Model

Parameter	Value	Type of Value
α	0,0168	Estimate value
β	0,00692	Estimate value
π	0,0081	Estimate value
μ	0,081	Estimate value
ω	0,05	Assumption values
δ	0,1912	Estimate value
k	0,2	Estimate value
ε	0,3	Estimate value
θ	0,891	Estimate value
γ	0,2	Assumption value

Simulation of model (5) will be carried out with parameter values according to Table 1 and initial conditions: $R(0) = 32{,}52$; $S(0) = 26{,}9$; $I(0) = 6.4965$, and $N(0) = 0.19$. The results of the model simulation were analyzed by looking at the trend of changes in stunting prevalence over time, as well as evaluating the impact of nutritional interventions on reducing stunting rates. The results of this simulation were used to (1) conclude the effectiveness of nutritional interventions in reducing stunting prevalence, and (2) provide recommendations for stunting management policies in Central Kalimantan. The next phase is to conduct a sensitivity analysis of the parameters that influence the prevalence of stunting. This analysis measures the relative change in a variable in response to changes in a specific parameter, while keeping other parameters constant. To quantify this sensitivity, we calculated the normalized sensitivity index, defined as the ratio of the relative change in the variable to the relative change in the parameter (Ziyadi & Yakubu, 2016; El Bhih et al., 2024). The normalized sensitivity index, C_p^V, for the variable, V, is defined as (Ziyadi & Yakubu, 2016):

$$C_p^V = \frac{\partial V}{\partial p} \times \frac{p}{V}. \tag{10}$$

C. RESULT AND DISCUSSION

1. Numerical Simulation

The results of the model simulation with Python with parameter values in Table 2 and initial conditions set is:

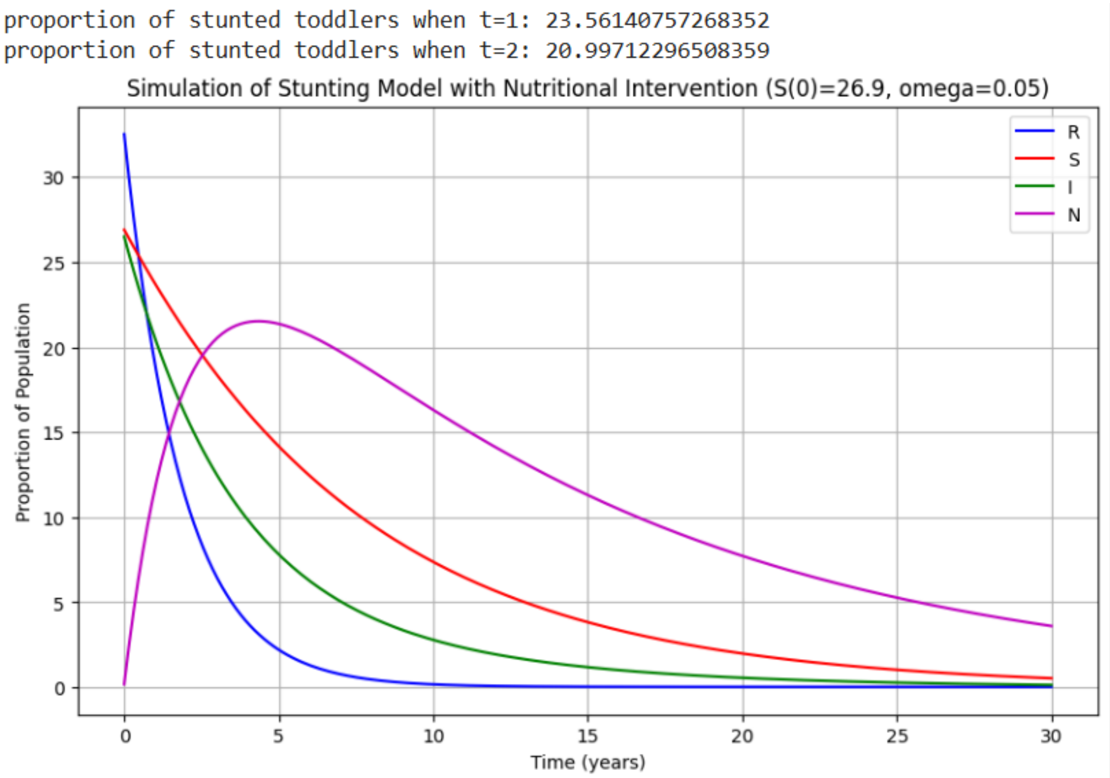

Figure 2. Simulation of Mathematical Model for Stunting with Nutritional Intervention

The simulation in Figure 2 provides an overview of how nutritional interventions can affect stunting dynamics, preventing stunting and helping recovery. From the graph, we can see how curve R decreased significantly over time. This indicates that nutritional interventions have succeeded in preventing toddlers at risk of become stunted. Curve S (stunting) also decreased although not as drastically as the R curve, this decrease indicates that by preventing more toddlers at risk of becoming stunted, the overall prevalence of stunting has also decreased. Curve I decreased significantly, this indicates the number of new toddlers entering group I decreased. Then, curve N increased over time, this indicates that nutritional interventions have succeeded in helping toddlers at risk of stunting to recover and achieve normal nutritional status. The simulation (Figure 2) starts at t=0, which is in 2022, where the prevalence of stunting is 26.9%. The simulation results show that a year later, at t=1, the prevalence of stunting has decreased by 3.16% to 23.74%. This figure is close to the prevalence of stunting in Central Kalimantan in 2023, which is 23.5%. In the following year, it is predicted that the prevalence of stunting will decrease again to 20.46%. The simulation starts at t=0, which is in 2022, where the prevalence of stunting is 26.9%. This shows the effectiveness of nutritional interventions in reducing the prevalence of stunting in Central Kalimantan.

2. Analysis of Equilibrium Point Stability

The Jacobian matrix of System of Equations (5) is:

$$J_f = \begin{bmatrix} -(\beta+\pi+\mu+\theta\varepsilon) & 0 & 0 & 0 \\ \beta & -(\omega+\mu) & 0 & 0 \\ \pi & \omega & -(k\delta+\mu+\gamma) & 0 \\ \theta\varepsilon & 0 & k\delta & -\mu \end{bmatrix}$$

Since the Jacobian matrix for both equilibrium points is the same, the local stability analysis for both point will also be the same. Next, this Jacobian matrix will be used in analyzing the local stability of the equilibrium points of the System of Equations (5). The characteristic polynomial of the Jacobian Matrix J_f is:

$$P(\lambda) = det(\lambda I - J_f)$$

$$= det \begin{bmatrix} \lambda+(\beta+\pi+\mu+\theta\varepsilon) & 0 & 0 & 0 \\ -\beta & \lambda+(\omega+\mu) & 0 & 0 \\ -\pi & -\omega & \lambda+(k\delta+\mu+\gamma) & 0 \\ -\theta\varepsilon & 0 & -k\delta & \lambda+\mu \end{bmatrix}$$

Furthermore, using the cofactor method, we obtain

$$P(\lambda) = (\lambda+(\beta+\pi+\mu+\theta\varepsilon))(\lambda+(\omega+\mu))(\lambda+(k\delta+\mu+\gamma))(\lambda+\mu) \quad (10)$$

The characteristic equation of Equation (10) is:

$$\big(\lambda+(\beta+\pi+\mu+\theta\varepsilon)\big)\big(\lambda+(\omega+\mu)\big)\big(\lambda+(k\delta+\mu+\gamma)\big)(\lambda+\mu) = 0 \quad (11)$$

As a result, we obtain eigenvalues that satisfy Equation (11), namely:

$$\lambda_1 = -(\beta+\pi+\mu+\theta\varepsilon), \lambda_2 = -(\omega+\mu), \lambda_3 = -(k\delta+\mu+\gamma), \text{and } \lambda_4 = -\mu.$$

It is known that the parameters in each equation are positive so that $\lambda_1 < 0, \lambda_2 < 0, \lambda_3 < 0,$ and $\lambda_4 < 0$. Since all the real parts of the eigenvalues are negative, the system Equation (5) that describes the dynamics of stunting in toddlers in Central Kalimantan with a focus on nutritional interventions is locally asymptotically stable at the equilibrium point (R_0, S_0, I_0, N_0) and (R^*, S^*, I^*, P^*). This is a certain condition in the model where the proportion of toddlers in each group (R, S, I, and P) remains constant. If there is a small change in this proportion, the system will tend to return to that equilibrium condition slowly over time.

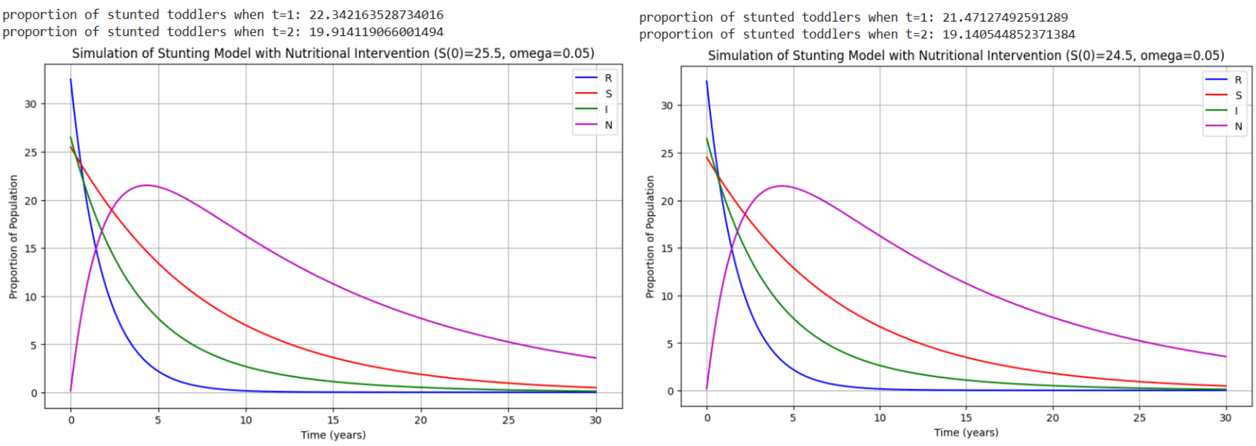

Figure 3. Simulation of locally asymptotically stable equilibrium point of the system with initial condition of S (S(0)=25.5 and S(0)=24.5)

Negative eigenvalues indicate a locally asymptotically stable equilibrium point of the system. A stable system is visualized by a simulation graph that approaches the equilibrium point. This is in accordance with Figure 3 which shows the variation of the initial value of the proportion of stunted toddlers, namely S(0)=25.5 and S(0)=24.5. Both simulation graphs show the proportion of stunted toddlers (S(t)) approaching 0 over time.

3. Analysis of Sensitivity

We conducted a local sensitivity analysis to identify crucial factors influencing stunting prevalence and prioritize them in intervention plans. The normalized sensitivity index, C_p^V, for the proportion of stunted toddlers in a state of equilibrium, S^*, is defined as:

$$C_p^{S^*} = \frac{\partial S^*}{\partial p} \times \frac{p}{S^*},$$

with $S^* = \frac{\beta\alpha}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)}$ and p is a selected parameter. We selected parameters $\alpha, \beta, \theta, \varepsilon$, and ω that may have a significant influence on the prevalence of stunting with parameter values according to Table 2. The normalized sensitivity index of parameter α for S^* is:

$$\begin{aligned} C_\alpha^{S^*} &= \frac{\partial S^*}{\partial \alpha} \times \frac{\alpha}{S^*} \\ &= \frac{\partial}{\partial \alpha}\left(\frac{\beta\alpha}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)}\right) \times \frac{\alpha}{S^*} \\ &= \frac{\beta}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)} \times \frac{\alpha}{\frac{\beta\alpha}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)}} \\ &= 1 \end{aligned}$$

The same procedure is performed to calculate the sensitivity indices of other parameters. The results obtained are summarized in Table 3.

Table 3. Normalized Sensitivity Index of Five Parameters to S^*

Parameter	Value	Equation of Sensitivity	Normalized Sensitivity Index	$S^* = 0.00244$	
				p-20%	p+20%
α	0,0168	1	1	0.00084	0.01764
β	0,00692	$\frac{(\omega+\mu)(\pi+\mu+\theta\varepsilon)}{(\beta+\pi+\mu+\theta\varepsilon)}$	0.1285049	0.00195	0.00059
π	0,0081	$\frac{-\alpha\beta}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)^2}$	0.006723	0.0077	0.00851
ω	0,05	$\frac{\omega}{(\omega+\mu)}$	0.381679	0.0475	0.0525
ε	0,3	$\frac{-\alpha\beta\theta}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)^2}$	-0.005991	0.285	0.315
θ	0,891	$\frac{-\alpha\beta\varepsilon}{(\omega+\mu)(\beta+\pi+\mu+\theta\varepsilon)^2}$	-0.0020169	0.8465	0.9356

Table 3 shows the parameters, parameter values, sensitivity equations, sensitivity index values and changes in S^* values. If there is a change in parameter value of 20%, then p-20% indicates that the parameter value decreases by 20% and p+20% indicates that the parameter value increases by 20% from the previous value. The results of the analysis show that the parameter α, the rate of entry of new toddlers into the group at risk of stunting, is the parameter that has the most influence on changes in the proportion of toddlers at risk of stunting or the prevalence of stunting. High α value indicates a high rate of entry of new toddlers into the stunting risk group (R). This means that more toddlers have the potential to become stunted. Although nutritional interventions focus on prevention, if the "supply" of toddlers at risk of stunting continues to increase, then the prevalence of stunting will remain high.

The next parameter that influences the prevalence of stunting is, ω, namely the transition rate of toddlers from the group of stunted toddlers (S) to the group of toddlers receiving nutritional intervention (I). Although stunted toddlers (S) are assumed not to recover after receiving nutritional intervention, increasing ω will accelerate the movement of toddlers from compartment S to compartment I (receiving intervention), as a result the rate of increase in the number of stunted toddlers is slowed down, so that the overall prevalence of stunting will decrease. In this case, nutritional intervention remains important to reduce the negative impacts of stunting, such as improving health status, supporting cognitive development, and preventing further complications. At least nutritional intervention continues to contribute to improving their quality of life and reducing the overall burden of stunting.

D. CONCLUSION AND SUGGESTIONS

This model simulates nutritional interventions that focus on two things: (1) prevention of stunting in toddlers at risk of stunting through growth monitoring programs, nutritional counselling, and provision of additional food; and (2) intensive care for stunted toddlers by ensuring their access to comprehensive health services, including health checks, nutritional supplementation, and assistance by health workers." This simulation shows that nutritional interventions have a positive impact in reducing the prevalence of stunting. Model simulation shows the effectiveness of the intervention in preventing stunting and helping recovery. Nutritional interventions have successfully reduced the prevalence of stunting in Central

Kalimantan by 3.16% and increased the number of toddlers at risk of stunting who managed to achieve normal nutritional status after receiving nutritional interventions by 7%. It can be concluded that early intervention in toddlers at risk of stunting is very important to prevent stunting, and targeted intervention in stunted toddlers is also needed to accelerate recovery and reduce the overall prevalence of stunting.

Based on the findings of this study, it is recommended that the government prioritize early interventions, such as growth monitoring programs integrated with integrated health posts, nutritional counseling by qualified health cadres, and provision of additional food through collaboration between the public and private sectors. The success of a program in Bangladesh that increased children' nutritional intake by using fortified rice and eggs could be replicated by this supplemental feeding program. In addition, it is necessary to improve focused care for toddlers with stunted growth by ensuring their access to comprehensive health services, including routine health checks, provision of nutritional supplements, and support from professional health workers. This program can follow Peru's model, which involves having health professionals visit homes to give stunted kids growth monitoring, developmental stimulation, and nutritional information.

ACKNOWLEDGEMENT

The authors would like to thank The DRTPM of Ministry of Education, Culture, Research and Technology for funding this research under the Grant of Penelitian Dosen Pemula (PDP), and also The Health Service, Bappedalitbang, BKKBN, and TPPS of the Central Kalimantan Province who have assisted researchers in collecting data for this research.

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