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Malnutrition Due to Climate Change in West Sumatra using Structural Equation Modeling with Partial Least Squares Approach

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Abstract

The Climate change exacerbates people's access to nutritious food and the risk of malnutrition, especially for vulnerable groups. West Sumatra's stunting rate in 2022 is above the national average. It is necessary to know the factors that influence malnutrition. The study uses primary data with a questionnaire on heads of farmer and fisher families in areas vulnerable to climate change in West Sumatra, Indonesia, in 2024. We took a probability proportionate size sample of 305 and analysed it using Structural Equation Modelling with Partial Least Squares. The results showed a malnutrition incidence of 76.4%. Environmental health directly influenced infectious diseases, which in turn affected malnutrition, resulting in a large total effect of 0.113 (11.3%). Environmental health indirectly impacts malnutrition through disease, resulting in a substantial total effect of 0.309 (30.9%). Adaptation had a direct effect on malnutrition and a large total effect of 0.197 (19.7%). Dietary patterns do not have a significant effect on malnutrition. Adaptation to change includes reducing the incidence of infectious diseases and improving access to sanitation. We need adaptation strategies to enhance environmental health and manage infectious diseases.

Introduction

Child malnutrition is still a global health problem. About 148.1 million (22.3 percent) children under 5 years old suffer from stunting, 45 million (6.8 percent) are wasting, and 37 million (5.6 percent) are overweight (Burki, 2022). Most low- and middle-income countries, including Indonesia, suffer from these three types of malnutrition. There were 9.8 percent underweight toddlers, 13.8 percent stunting, 7.9 percent wasting, and 7.6 percent overweight (Ministry of Health, 2023). Malnutrition has caused the deaths of 3.5 million children and mothers, and 35 percent of malnutrition occurs in children under the age of 4-5 years (Confalonieri, Menezes, and Souza, 2015). Malnutrition has caused the deaths of 3.5 million children and mothers, and 35 percent of malnutrition occurs in children under the age of 4-5 years (Kemenkes RI, 2023; Kusumawati *et al*., 2015; WHO, 2023).

Climate change will further exacerbate malnutrition in children. Children who are malnourished and food-insecure are particularly vulnerable to climate change-related hazards, which are further exacerbated by poverty. The UNICEF Children's Climate Risk Index in 2021 places Indonesia in the top

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three rankings of countries where children are exposed to various impacts of climate change and climate-related shocks. Geographical characteristics, socio-economic conditions, malnutrition, food insecurity, and poverty show different severity throughout Indonesia. West Sumatra is one of 15 provinces that are highly vulnerable to the combined impacts of climate change and malnutrition, with a high malnutrition prevalence (12.5-15.5 percent), moderate food insecurity (4.2-6.7 percent), and a moderate disaster risk index (0.17-0.39) (WHO, 2023).

Climate change will damage agricultural land, reduce crop productivity, and affect food security, especially in developing countries that are more vulnerable to natural disasters. Increased carbon dioxide levels can lead to a decrease in crop nutritional quality, potentially lowering the levels of protein, iron, and zinc in major food crops like rice and wheat. This decrease in nutrient content risks increasing malnutrition problems in populations that depend on these crops as their main source of nutrition (Myers *et al*., 2017). Decreased zinc supplies lead to lower z-scores for age and increased stunting rates (Amondo, Nshakira-Rukundo, and Mirzabaev, 2023). The risk of hunger and malnutrition could increase by 20% by 2050. The majority of child deaths due to climate change are driven by malnutrition (WHO, 2023).

Climate-related food systems are increasingly becoming a threat to health. Climate change undermines the basic determinants of child nutrition by affecting the quantity and quality of food available and accessible to children and families, limiting parenting to provide adequate feeding practices and influence, and disrupting access to essential health and nutrition services. Climate change often leads to rising food prices, which limit poor people's access to healthy food (Myers *et al*., 2017). In addition, the degradation of marine and coastal ecosystems due to global warming and ocean acidification is impacting the fisheries sector, which is the main source of protein for millions of the world's populations. Climate change exacerbates barriers to accessing health services. Health shocks and stresses push millions of people into poverty every year (WHO, 2023). Inadequate feeding practices, food insecurity, and limited access to health services lead to malnutrition. The industrialization of the food system causes a double burden of malnutrition (Agostoni *et al*., 2023). Limited resources to buy or produce food cause difficulty in meeting nutritional needs (WHO, 2023).

The impact of climate change on nutrition can have long-term consequences on children's growth and development. Stunted children can experience decreased cognitive development, lower educational attainment, and reduced economic potential in adulthood. Stunted toddlers are more susceptible to disease, and adults are at risk of degenerative diseases such as obesity, glucose tolerance, coronary heart disease, hypertension, osteoporosis, and decreased performance and productivity (Ahmed *et al.*, 2023; Kemenkes RI, 2023; Rolfe *et al.*, 2018; Soliman *et al.*, 2021). The potential impact of climate change requires anticipatory measures by designing and implementing effective adaptation and mitigation strategies that are able to support the main determinants of child nutrition and ensure the health and well-being of all children. This study aims to identify the issues and factors that lead to malnutrition in areas affected by climate change in West Sumatra using a method called Partial Least Squares (PLS) analysis, which is part of Structural Equation Modeling (SEM).

Method

The researcher designed a questionnaire and used it to collect primary data for this study. Farmers and fishermen in West Sumatra Province's climate-vulnerable areas filled out this questionnaire during interviews. The population in this study was farmer and fisher families in five areas vulnerable to climate change in West Sumatra, namely West Pasaman, South Coast, Padang Pariaman, Solok, and Padang. The sample size formula yielded 305 samples from the population. The sample used in this study was the minimum sample size standard according to the assumptions in SEM, namely, 100 samples. We sampled each area vulnerable to climate change using the proportional random sampling method.

This study explains the results of data

analysis using *structural equation modeling* (SEM) on malnutrition. To obtain the value of the variables studied, each observed variable is composed based on its group in SEM, which is called the *loading factor/outer loading value.* Variable composites test the validity of data on the observed variable in the latent/unobserved variable or how much the latent variable explains the indicator's variance. In studies that are still being developed or tested, the standard composite value or loading factor is achieved by using a tolerance value of 0.5-0.6 or higher than 0.7 (Pering, 2021). The significance test in the SEM model with PLS aims to determine the influence of exogenous variables on endogenous variables. Hypothesis testing with the SEM PLS method was carried out by bootstrapping with the help of the SmartPLS 3.0 computer program. Before the hypothesis was tested, it was known that the value of the T-table value for the confidence level was 95% (α 5%) and the degree of freedom (df) = n-2 was 1.96.

Result and Discussion

This study explains the results of data analysis using *structural equation modeling* (SEM) on malnutrition. To obtain the values of the variables studied, each observed variable is first composited based on its group in SEM (*loading factor/outer loading value).* Structural Model Design (Inner Model) on Figure 1 displays descriptions of latent variables and their manifest variables.

The output shows that the loading factor gives a value above the recommended 0.5. This study's indicators have demonstrated their validity. In figure 2*, we get information from the outer loading/loading factors for each variable: the disease variable (X1), which includes infectious disease (X1.1); the food pattern variable (X2), which shows purchasing power (X2.2); the environmental health variable (X3), which indicates access to sanitation (X3.1); and the health quality variable (X4), which includes (X4.2) and PHBS (X4.3).* The climate change adaptation variable (X5) provides information about the indicators. The analysis shows that the outer model's invalid data has been removed, leaving only valid data from the observed variable values to get the path coefficient in the inner model. Figure 3 illustrates this.

We obtained the path coefficient and significant level (T-value) of the determinant factor against malnutrition based on Figures 3 and 4. The data revealed the presence of both affecting and non-affecting factors on the variable :

a. Testing of the Environmental health variable (X3) against infectious diseases (X1)

Ho : X3 = X1

Hi : X3 ≠ X1

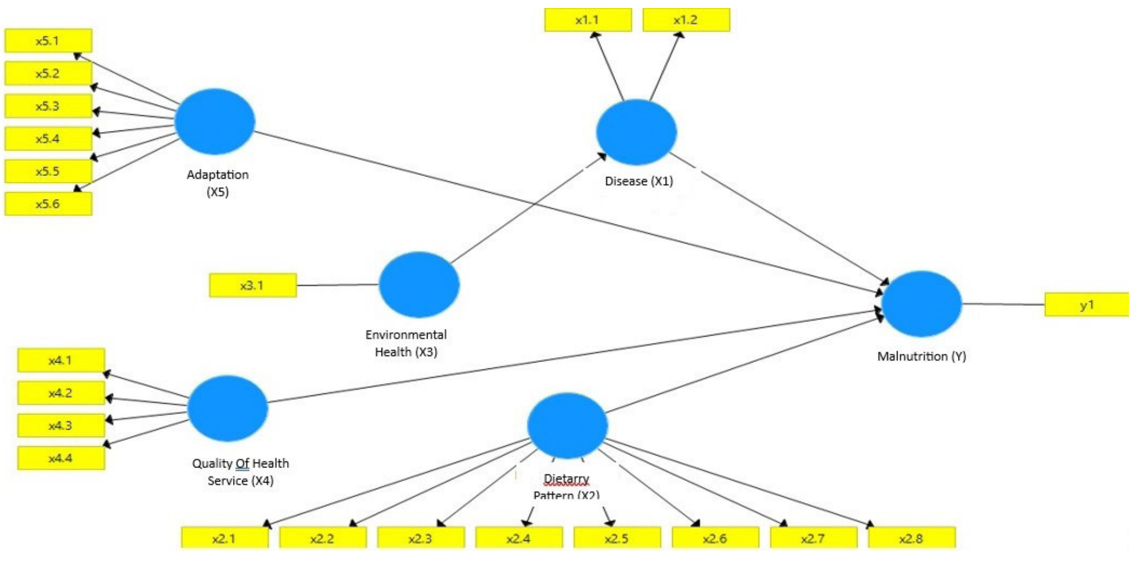
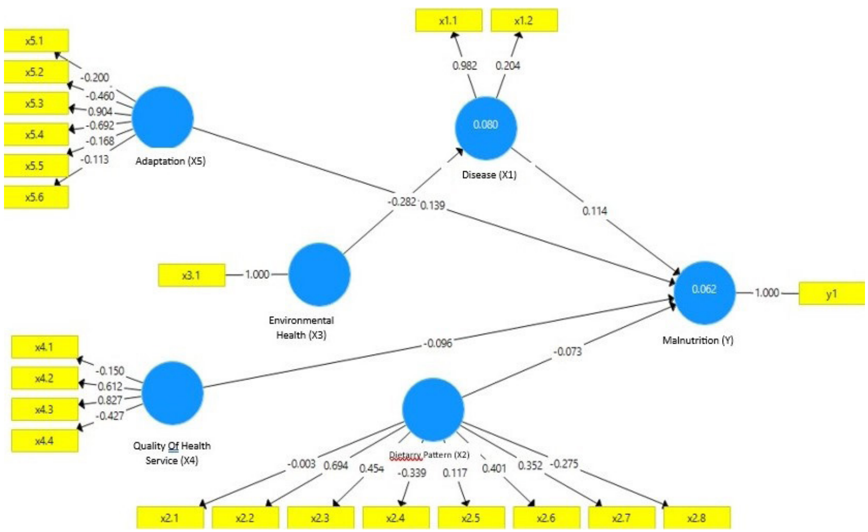


Figure 1. Preliminary Model of the Influence of Determinant Factors on Malnutrition

Structural Model Design (Inner Model) The latent variables and their manifest variables are described in Table 1.

Table 1. Exogenous Variables and Indicators

Variable excretion	Manifest variable (Indicator)	Symbol
Malnutrition (Y)	Malnutrition	Y
Disease (X1)	Infectious diseases	X1.1
	Non-Infectious Diseases	X1.2
Dietary Patterns (X2)	Food availability	X2.1
	Purchasing power	X2.2
	Access to food	X2.3
	Income	X2.4
	Consumption	X2.5
	Land	X2.6
	Agricultural Production	X2.7
	Fisheries production	X2.8
Environmental health (X3)	Sanitation access	X3.1
Quality of health services (X4)	Maternal and Child Health	X4.1
	Health care support	X4.2
	Clean and Healthy Living Behavior/PHBS	X4.3
	Health services	X4.4
Adaptive behavior (X5)	Climate Change Information	X5.1
	Adaptive behavior	X5.2
	Life skill	X5.3
	Self-Efficacy	X5.4
	Education	X5.5
	Gender	X5.6



Description : * valid

Figure 2. Outer Loading Value for Each Variable

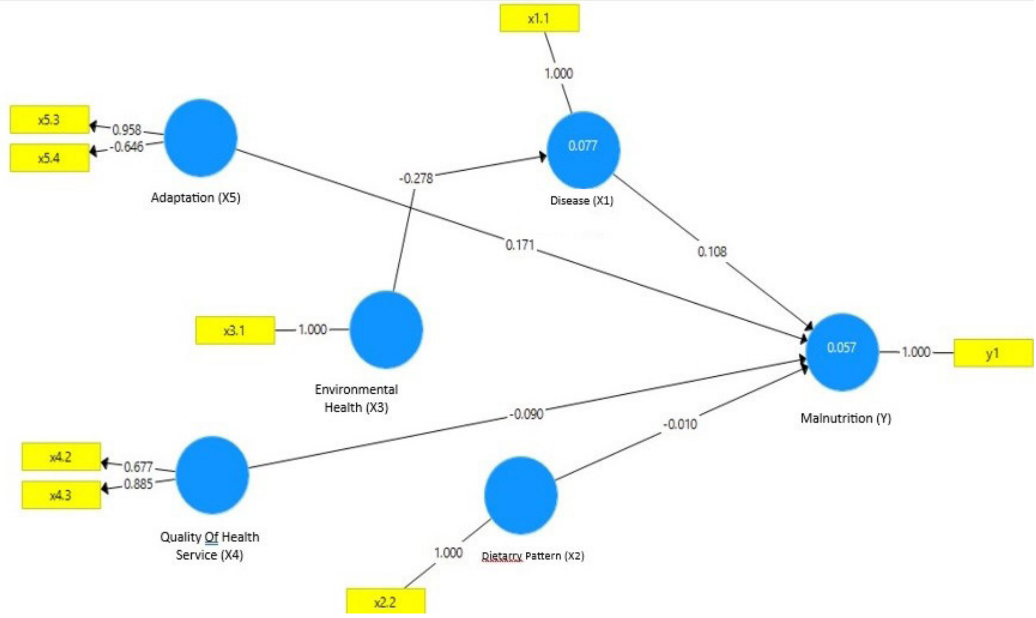


Figure 3. The Path Coefficient Value Using the SEM Method

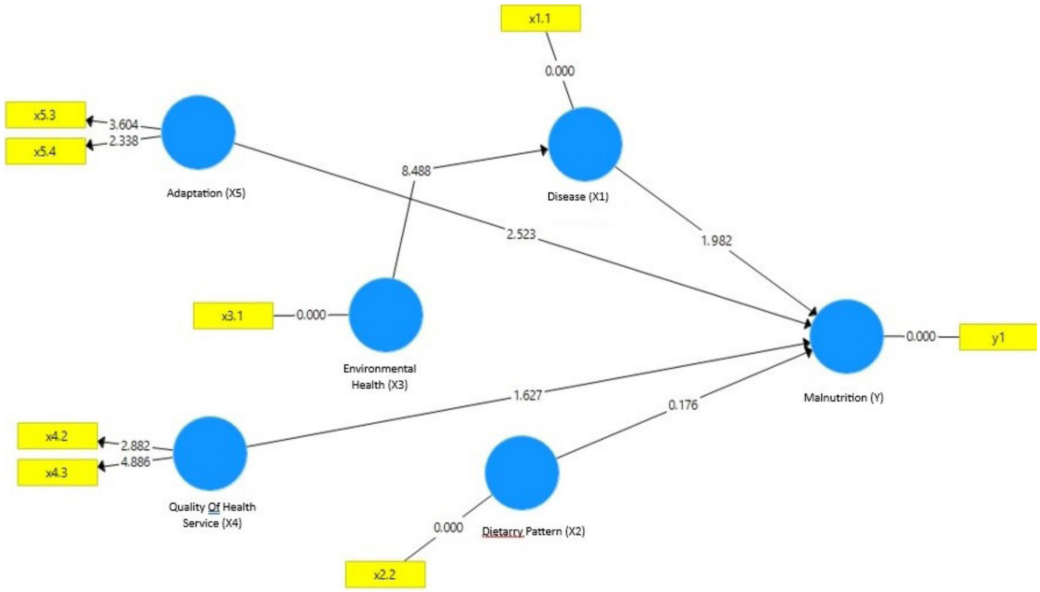


Figure 4. Significant Level Value (T-value) Using the SEM Method

The statistical test results from the SEM method showed a T-value of 8.488 with a 95% confidence level for environmental health (X3) affecting infectious diseases (X1), since 8.488 is greater than 1.96. This shows that environmental health has a significant effect on infectious diseases. The effect of environmental health has a pathway coefficient (β) of -0.278 on infectious diseases, meaning that the direction is negative. This shows that the lower the environmental health condition, the higher the incidence of infectious diseases by 27.8%, and vice versa.

b. Testing of the infectious disease variable (X1) against malnutrition (Y)

Ho : X1 = Y

Hi : X1 ≠ Y

The pathway analysis results from the SEM method showed a T-value of 1.982 with a 95% confidence level. Infectious disease (X1) against malnutrition (Y): Value 1.982 > 1.96. This evidence shows that infectious diseases have a significant effect on malnutrition. The

Table 2. The Result of the Significance Level and the Path Coefficient Using the Method of Structural Equation Modeling (SEM) on Malnutrition

Variable	Path coefficient	T –*value*	R square
Infectious and Non Diseases (X1) -> Malnutrition (Y)	0,113	1,997	
Environmental Health (X3)-> Infectious and Non-Infectious Diseases (X1)	-0,278	8,181	0,050 (Y)
Adaptation (X5) -> Malnutrition (Y)	0,197	3,652	

effect of infectious diseases having a pathway coefficient (β) of 0.108 on malnutrition means that the direction is positive. This shows that the higher the infectious disease, the higher the incidence of malnutrition by 10.8%, and vice versa.

c. Testing of Food Pattern variables (X2) for Malnutrition (Y)

Ho : X2 = Y

Hi : X2 ≠ Y

The statistical test results from the SEM method showed a T-value of 0.176 with a 95% confidence level for the Food Pattern (X2) related to Malnutrition (Y), which is 0.176 < 1.96. This indicates that dietary patterns do not significantly affect malnutrition. This shows that dietary patterns do not have a significant effect on malnutrition.

d. Testing of the Health Service Quality variable (X4) against Malnutrition (Y)

Ho : X4 = Y

Hi : X4 ≠ Y

The results of the path analysis statistical test using the SEM method obtained *a T-value* of 1.627 with a 95% confidence level. Quality of Health Services (X4) on Malnutrition (Y) Value 1.627 < 1.96. This analysis shows that the quality of health services does not have a significant effect on malnutrition.

e. Testing the variable Adaptation (X5) to Malnutrition (Y)

Ho X5 = Y

Hi X5 ≠ Y

The statistical test of pathway analysis using the SEM method yielded a T-value of 2.523 with a 95% confidence level. The adaptation (X5) to the malnutrition value of 2.523 exceeds 1.96. This shows that adaptation has a significant effect on malnutrition. The effect of adaptation has a path coefficient (β) of -0.171 on malnutrition, meaning that the direction is negative. This result shows that the better the adaptation, the lower the incidence of malnutrition by 17.1%, and vice versa.

Using Table 2, a path analysis was created with the Structural Equation Modeling (SEM) method, and the results were interpreted to provide the following information from the path analysis:

a. Infectious and non-infectious diseases (X_1)

The direct effect of infectious and non-infectious diseases (X1) on malnutrition (Y) is 0.113.

Structural Equation X1 against Y: Pyx1 X1 + $_{y}$ = 0.113X1 + $_{y}$

Based on the results of the pathway analysis using the SEM method, it was found that infectious diseases had a direct effect on malnutrition, with a total of 0.113 (11.3%).

b. Environmental Health (X_3)

Direct effect of environmental health (X3) on infectious and non-infectious diseases (X1) = -0.278

Structural Equation X3 to X1: Px1x3 X3 + $_{x1}$ = -0.278X3 + $_{x1}$

Based on the results of the path analysis using the SEM method, it was found that environmental health had a direct effect on infectious and non-infectious diseases with a total influence of -0.278 (27.8%). We found the indirect effect of environmental health (X3) on malnutrition (Y) through infectious and non-infectious diseases (X1) to be -0.031. Overall total = -0.278 + (-0.031) = -0.309. The path analysis using the SEM method revealed that environmental health affected malnutrition indirectly by influencing both infectious and non-infectious diseases, resulting in a total effect of 0.309 (30.9%).

c. Adaptation (X5)

Direct effect of adaptation (X5) on malnutrition (Y) = 0.197

Structural Equation X5 to Y: Pyx5 X5 + $_{y}$ = 0.197X5 + $_{y}$

Based on the results of the pathway analysis using the SEM method, it was found that adaptation had a direct effect on malnutrition, with a total of 0.197 (19.7%).

In accordance with the results and interpretations above, a total structural equation is formed:

$$Y = P_{yx1} X_1 + P_{yx5} X_5 + P_{y\ ;}\ \text{R Square}$$
$$= 0{,}113X_1 + 0{,}197X_5 + 0{,}950;\ 0{,}050d$$

Malnutrition is a state of deficiencies, excesses, or imbalances of nutrients that can cause adverse effects on the body. The results of the study found that the incidence of malnutrition in family members in vulnerable areas in West Sumatra province was 76.4% (agriculture 72.9% and coastal 81.5%). Overall, the prevalence of double burden of malnutrition at the household level was < 30% with a lower prevalence in Asian countries (Sufyan, *et al*., 2024). Children with growth failure severe enough to be recognized as "failure to grow" are assessed as malnourished (Bouma, 2017). In line with research in Pakistan, it showed that the proportion of children and adolescents who were underweight was 25.1%, stunting 23%, wasting 24%, malnutrition 12.5%, and obesity 6.9(Khan *et al*., 2022).

Agricultural and coastal areas contribute to the increase in malnutrition in West Sumatra. Despite the abundance of nutrients found in coastal and agricultural areas, particularly in fish protein, meat, vegetables, rice, seaweed, and other marine products, malnutrition still persists in these areas. If protein intake is met, then the growth and development process can run smoothly, and the body's immune system functions properly. The most studied factors affecting malnutrition in coastal areas are related to protein intake (Andyarini, 2017). The results of the SEM test show that environmental health diseases have an influence on infectious diseases in areas vulnerable to climate change. Poor sanitation exacerbates the impacts of climate change, increasing the risk of infectious diseases such as diarrhea, cholera, and dengue fever, especially during droughts or floods. Access to drinking water and quality water reduces the risk of diarrhea by 52%, latrine access by 24%, sewage disposal by 47%, and handwashing behaviour with soap by 30% (Wolf *et al*., 2022). Clean water sources have a 12 times greater risk of getting diarrhea (Maliga *et al*., 2022).

Climate change is increasing the frequency and intensity of severe heatwaves, droughts, extreme rainfall, and cyclones in many regions and modifying the transmission of food, water, and zoonotic infectious diseases, resulting in a major impact on health (WHO, 2023). Based on the SEM model, a *T-value* of 8.488 was obtained with a confidence level of 95% > 1.96, indicating that environmental health has a significant effect on malnutrition. The pathway coefficient (β) of -0.278 means that the lower the environmental health, the higher the incidence of malnutrition by 27.8%, and vice versa. Research in climate-prone areas shows that lower temperatures lower the immune response of body cells, which are more susceptible to viral infections that attack the respiratory system. This is due to the body's need to adjust to new air temperatures and humidity levels. Chronic respiratory diseases are among the most vulnerable groups to the adverse impacts of climate change. There is a relationship between climate factors and respiratory disorders (D'Amato *et al*., 2016).

Children who have a history of infectious disease have a risk of stunting 2.2 times higher than children who do not have a history of infectious disease (Wulandary *et al*., 2024). Infectious diseases cause toddlers to lose weight due to increased metabolism and decreased appetite. Continuous weight loss can lead to a decrease in nutritional status (Philipsborn and Chan, 2018). Research by Wea, Jutomo and Boeky (2023) also revealed a correlation between infectious diseases and protein intake and the incidence of stunting. Stunted toddlers have a history of illness more often than non-stunted toddlers (Nurbawena *et al*., 2021).

The results of the SEM test show that

there is an indirect influence of environmental health on malnutrition through infectious and non-infectious diseases in climate-prone areas in agricultural and coastal climate change-prone areas. The evidence shows that poor environmental health conditions cause infectious diseases and affect the incidence of malnutrition. Environmental sanitation and infectious diseases are one of the determining factors for stunting in children under five. Poor sanitation is associated with an increased risk of infectious diseases that can cause stunting in children under five (Aprihatin *et al*., 2020). The influence of water, sanitation, and hygiene in preventing infectious diseases and acute malnutrition (Hernandez *et al*., 2021). The Indonesian Family Life Survey, controlling for a series of factors, water and sanitation conditions, and household poverty, greatly affects chronic malnutrition in children in Indonesia (De Silva and Sumarto, 2018). Economic factors and environmental factors are two factors that have a large enough impact on the occurrence of stunting (Nugroho, 2023). Children living in rural areas experience a higher prevalence of severe food poverty compared to children living in urban areas.

Based on the results of the pathway analysis using the SEM method, it was found that adaptation had a direct effect on malnutrition. According to the BMKG report, in 2022, Indonesia experienced a longer drought than the previous year, and this caused a shift in the rice planting season. This condition will change the social and economic aspects of the community. Changes in fishery stocks (fish, shrimp, etc.) will lead to a reduction in sea protein sources. This will significantly impact the national food security situation, particularly in terms of fulfilling community nutrition needs. Adaptation to change includes reducing the incidence of infectious diseases, improving access to water/sanitation, and improving food security and gender equality. The need for targeted interventions and policies to address the complex interplay of factors influencing malnutrition in vulnerable groups (Muflih *et al*., 2024). Gender-responsive interventions to enable women to cope with and adapt to the climate (Awiti, 2022). The economic level of the community is caused by a lack of catches, so it is very difficult for fishing families on the coast to encourage the achievement of local food security (Ashari, 2023). The strategies adopted to adapt to climate change have a significant impact on nutritional outcomes (Macheka *et al*., 2022). Malnutrition and climate change can bring together diverse and different constituents around the world (Swinburn *et al*., 2019).

Conclusion

The results of the study found that the incidence of malnutrition in family members in vulnerable areas in West Sumatra province was 76.4% (agriculture 72.9% and coastal 81.5%). The pathway analysis using the SEM method revealed a direct relationship between infectious diseases and malnutrition. Environmental health directly influences both infectious and non-infectious diseases. Environmental health indirectly influences malnutrition through both infectious and non-infectious diseases. Adaptation has a direct effect on malnutrition. Adaptation to change includes reducing the incidence of infectious diseases, improving access to water/sanitation, and improving food security and gender equality. Adaptation strategies are needed in the form of funding, design, evaluation, and reporting of standards on the impact of responses to climate change adaptation on health and evidence-based policy actions.

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