Spatial Analysis of Drought Vulnerability Related to Climate Change and Under Five Children's Nutritional Status

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Abstract. Drought vulnerability which more prevalent due to climate change reduce public health quality. This research aims to map areas that are vulnerable to drought and correlate them with under five children nutritional status. This was a cross-sectional study using spatial analysis in Borobudur District. Drought vulnerabilities were overlayed using three drought-prone indicators of Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Land Surface Temperature (LST). The spatial analysis found 8 villages (40%) had high, 6 villages (30%) had medium, and 6 villages (30%) had low drought vulnerability. Stunting prevalence derived from the routine community-based nutritional surveillance of the Magelang District Health Office. Analysis of Variance (ANOVA) were used to assess the risk of stunting among different level of spatial indicators related to drought. The average prevalence of stunting was higher in the areas with high (12.57%), compared to medium (8.93%), and low (8.73%) drought vulnerability, but not statistically significant ($F=1.763$; $p>0.05$). Stunting was significantly related to water availability (NDWI). A lower NDWI index increased the risk of stunting in children ($F=4.620$; $p<0.05$). NDWI spatial analysis can be used as a reference to support preventive efforts to mitigate drought and the nutritional status of children in rural areas.

1 Introduction

According to the World Health Organization, climate change is the most serious health hazard to humanity. The cost of direct health losses (excluding expenses in health-determining sectors such as agriculture, water, and sanitation) is predicted to reach between USD 2-4 billion per year by 2030 [1]. Climate change is a global health emergency, this is because it has emerged as an urgent global issue and poses major

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challenges to society and the environment. Climate change causes various significant environmental problems, including increasing global temperatures, changing weather patterns, drought, ecosystem damage, increasing ocean acidity and health [2].

Indonesia is a country that has the potential for extreme temperature increases, this is due to global climate change, El Nino and La Nina, global warming and the greenhouse effect as well as the diverse geography and topography in Indonesia which can influence the distribution of low rainfall and can affect the severe and frequent droughts occur in various regions in Indonesia. This combination of factors makes Indonesia vulnerable to extreme temperature increases, which can have serious impacts on the environment, human health and economic sustainability. Drought is one of the consequences of climate change which contributes significantly to health through food insecurity, which will ultimately have an impact on malnutrition and stunting in children. The impact of drought on health occurs because one of them is a lack of access to adequate and nutritious food [3, 4].

Poor sanitation and hygiene conditions are one of the main causes of malnutrition in children under five years of age. These conditions at home can result in chronic exposure to environmental pathogens that cause changes in the morphology and function of the gut microbiota and can ultimately lead to stunting in children. There is strong evidence between environmental factors and chronic inflammatory syndrome of the intestine, and this condition is known as pediatric environmental enteropathy. These diseases further affect the development and growth of children and disrupt their gut microbiota. Diarrhea is a major factor causing malnutrition, caused by intestinal microbiota pathogens. Such enteric infections can cause stunting and wasting due to malabsorption and intestinal barrier dysfunction [5,6]. A child's height at the second birthday is considered a predictor of cognitive development and overall health [7]. Further evidence reveals that nutritional, sociodemographic, environmental, cultural, and economic factors are important contributors to poor health outcomes in children under five years of age [8].

Central Java is one of the most vulnerable area to the impacts of extreme drought [9]. During El Niño in 2019, as many as 63% of areas in Central Java experienced extreme drought, including Magelang Regency. Borobudur district experiencing the worst drought among all sub-district in Magelang, both during El Niño in 2019 and 2023 [10]. This research aims to map areas that are vulnerable to drought and the nutritional status of children under five in Borobudur, and to analyse the relation between drought vulnerability and under-five nutritional status.

2 Material and Methods

This research used a cross-sectional study. We used spatial analysis to define the drought vulnerability and secondary data for under five children nutritional status in Borobudur District, Magelang Regency.

2.1 Dependent variable

The outcome variable in this study is the prevalence of stunting cases among children under five years old at the village level in the Borobudur sub-district. Data was obtained from the routine community-based nutritional surveillance of the Magelang District Health Office in February 2023. The category of the magnitude of the stunting problem based on its prevalence is categorized as follows: very low (<2.5%), low (2.5 to <10%), medium (10 to <20%), high (20 to <30%), very high (≥30%) [11].

2.2 Independent variables

Drought vulnerabilities were analysed using three indicators: Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Land Surface Temperature (LST). In the research, the degree of drought for each indicator was analysed by giving proportional weights where the data was obtained from Lansat 8 OLI satellite imagery, as well as using the QGIS version 3.24.

2.3 Study Area

Magelang Regency is one of the districts in Central Java Province, Indonesia. It has a total area of 1,085.73 km^2 and is located along the equator between 110^0 01^0 51^0 and 110^0 26^0 58^0 East Longitude, and from 7^0 19^0 13^0 to 7^0 42^0 16^0 South Latitude with the largest sub-district being Kajoran District with the area is 83.41 km^2 while Ngluwar sub-district is the smallest sub-district with 22.44 km^2 [12]. Borobudur District is one of 21 sub-districts in Magelang Regency. Borobudur District has an area of 54.55 Km^2 with 20 villages. Ngadiharjo Village is the largest village (5.90 km^2), and the smallest village is Tanjungsari Village (0.65 km^2) [13].

2.4 Data analysis

This study used two assessment components consisting of measurements using a spatial approach based on the environment and a population approach for the number of stunted toddlers in the Borobudur District area. The environmentally based spatial approach employed 3 indicators consisting of NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Wetness Index) and LST (Land Surface Temperature). NDVI is a vegetation index in an area that is commonly used to see the level of greenness of an area. NDVI is an indicator that is assessed from satellite imagery of an area that has long been used as an indicator of vegetation conditions related to drought. Meanwhile, the NDWI indicator is a wetness index that was developed to see the level of wetness of an area from satellite imagery [14]. NDWI is known to be related to plant water content, where the NDWI index is an index derived from the Short Wave Infrared (SWIR) and Near Infrared (NIR) channels. SWIR reflectance describes changes in vegetation water content and mesophyll structures such as sponges, several parameters captured by satellite imagery can be used as measurements in the NDWI index to see areas of drought in a region [15,16]. Meanwhile, LST is a measure of temperature on the ground surface that can be captured by satellites which can depict the heat of an area which can be linked to the dryness of that area [17]. These three indicators will be assessed per area point and then averaged within the village area in Borobudur District. The indicator values for each measurement will be analyzed in spatial combination with an overlay technique using the Quantum GIS application version 3.22 Biatowieza series. The overlay technique was used to identify three levels of vulnerability, which was divided into high, medium, and low vulnerability. Stunting parameters in children were also analysed and visualized in maps so that they can be overlaid with maps of drought vulnerability in rural areas.

Statistical test using Analysis of Variance (ANOVA) with LSD post-hoc was conducted to analyse the difference of drought vulnerability indicators on the prevalence of stunting in children under five years old. We carried out statistical analyses using the SPSS software.

2.5 Ethical clearance

The survey protocol underwent a comprehensive evaluation by the Indonesian Islamic University Health and Medical Research Ethics Committee and granted ethical clearance number 7/Ka.Kom.Et/70/KE/XI/2023.

3 Result

3.1 Spatial analysis on NDVI, NDWI, and LST in Borobudur, Magelang, Central Java

The research location was in Borobudur District, which is part of Magelang Regency, Central Java Province, Indonesia, which is located between 7.6° South Latitude and 110.16° and 110.2° East Longitude. This area is geographically located on hilly topography and is dominated by agricultural and plantation land use. Distribution maps of study indicators were created and analyzed in the study area at the village level. The distribution index was visualized to divide the status of each rural area consisting of NDVI, NDWI and LST, created to describe the index related to drought in each village in Borobudur District.

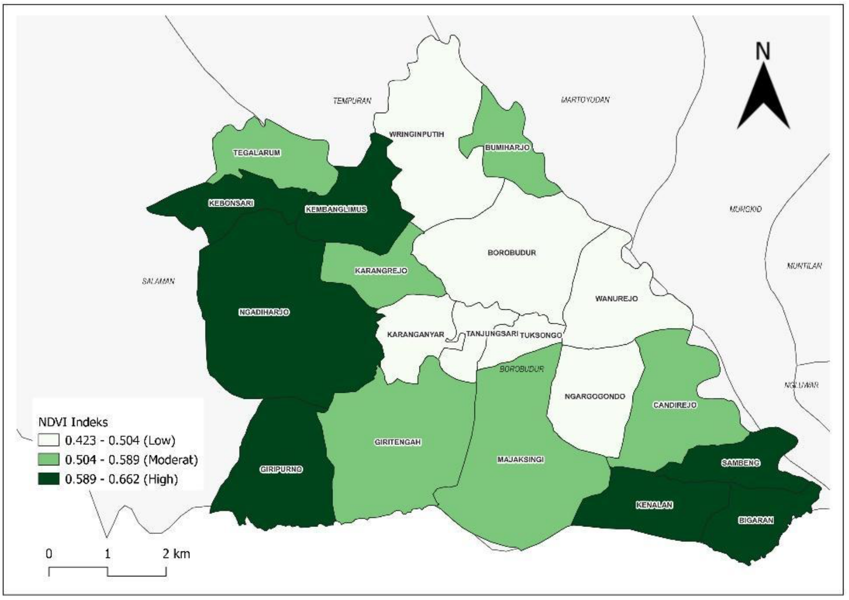

Fig. 1. *Spatial Distribution of Normalized Difference Vegetation Index (NDVI)*

Figure 1 shows the distribution of the Normalized Difference Vegetation Index (NDVI) variable in Borobudur District. The distribution of NDVI was related to drought in the region. The NDVI indicator looked high in almost all villages in the western region of the research area, Kebonsari, Kembanglimus, Ngadiharjo and Giripurno villages (NDVI Index > 0.589) and a small number of villages on the eastern side were Sambeng, Kenalan and Bigaran villages (NDVI I > 0.589). Villages with a low NDVI Index were clustered in the northern region (NDVI I < 0.504). The development of the area on the north side of Borobudur Regency, which is an international scale tourism area, encourages economic growth which ultimately creates an urban area dominated by buildings and other supporting infrastructure [17, 18]. This development will erode plants as water retainers and increase groundwater exploitation. Another impact is the increase in average temperature in the region [19,20]. Other evidence is that Tuksongo Village (NDVI index = 0.442) was the village with the lowest NDVI, which is a village that is very close to the new urban area which was formed due to the development of the area around the largest temple in the world, namely Borobudur Temple, while the village furthest from the urbanization center is an agricultural area and plantation is Giripurno village (NDVI I = 0.662).

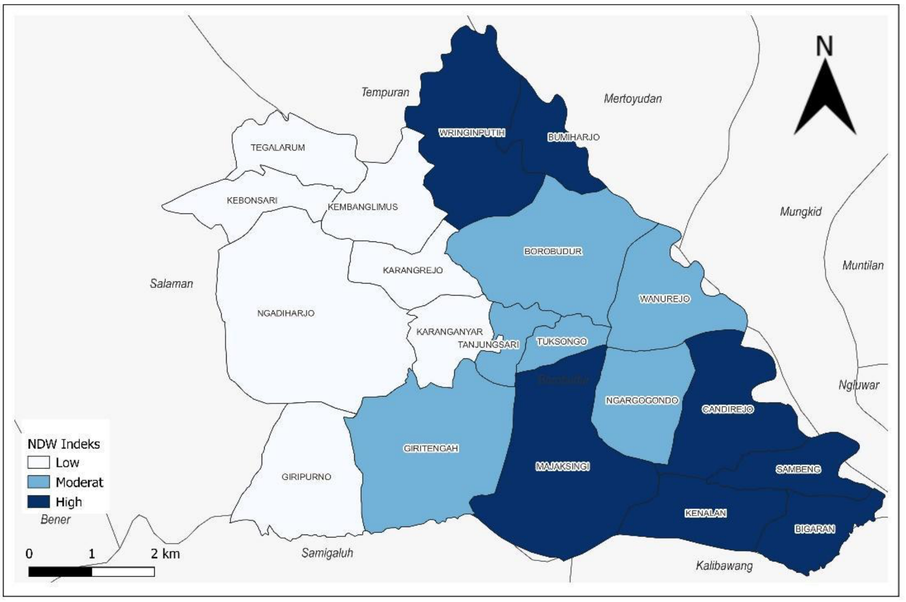

Fig. 2. *Spatial Distribution of Normalized Difference Wetness Index (NDWI)*

For the regional NDWI index at the village level, the index value was very small considering that the data in the study was collected during the dry season. The NDWI Index assesses the water content in an area using satellite imagery (Figure 2). To simplify data interpretation, the NDWI value was given a corrected value per 1000. The highest NDWI index was dominated by rural areas in the southern region, where the presence of the Kalibawang river helps provide water in that area. There were four villages with the highest NDWI Index consisting of the villages of Majaksingi, Candirejo, Kenalan, and Bigaran, meanwhile in the northern region there were the villages of Wringin Putih and Bumiharjo with high NDWI. Seven villages in the western region had a low NDWI index (Giripurno, Ngadiharjo, Karanganyar, Karangrejo, Kembanglimus, Kebonsari, and Tegalarum villages). The existence of rivers is a differentiator in the NDWI Index in Borobudur District, where 65% of villages in the eastern region are villages that have a moderate-high NDWI Index, namely areas close to 2 rivers (Progo river and Kalibawang river) [21].

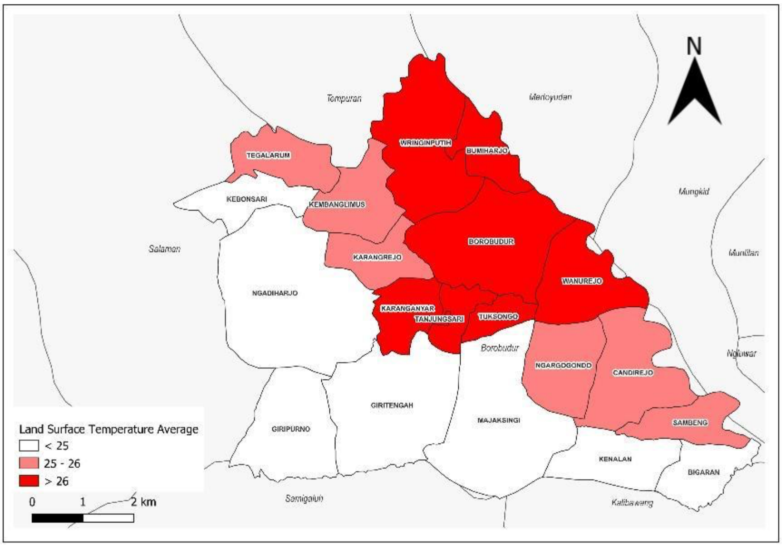

Fig. 3. *Spatial Distributionn of Land Surface Temperature (LST)*

The Land Surface Temperature Index in Figure 3 visualizes the temperature distribution above the earth's surface in the study area. This indicator analysis used the Google Earth Engine (GEE) application to view satellite images and extraction which can be analyzed using the GIS application to get the average temperature per region with rural area boundaries. The northern and northeastern regions of Borobudur District are areas with high temperatures, while the southern regions and the Southwest and West regions are regions with low temperatures in Borobudur District. Temperature differences between regions are not too extreme considering the small area of Borobudur sub-district. In overall analysis, 35% of regions have temperatures > 26^0 C (Wringinputih, Bumiharjo, Borobudur, Karanganyar, Tanjungsari, Tuksongo, Wanurejo), and 35% of regions have temperatures < 25^0 C. (Kebonsari, Ngadiharjo, Giripurno, Giritengah, Majaksingi, Kenalan, and Bigaran). Regional drought is related to surface temperature [22] and can be used as one of the parameters of drought in a region. LST indicators are influenced by the surface of the surrounding area, including the conditions of the NDVI Index and NDWI Index.

3.2 Spatial indicators on drought vulnerabilities and nutritional status among under-five children

3.2.1 Overlay Mapping

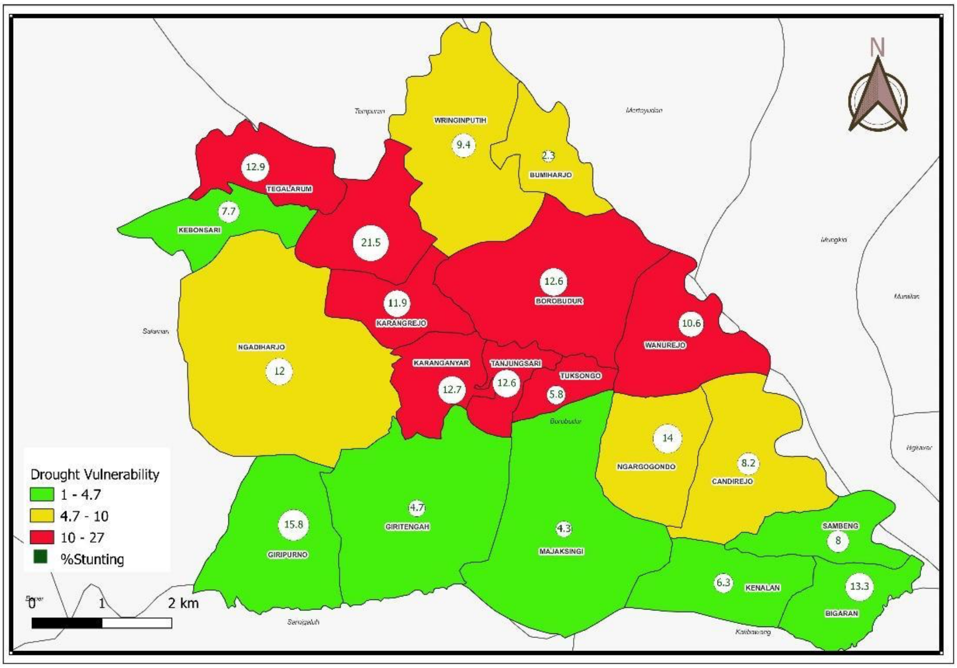

Fig. 4. Drought Vulnerability status of village areas and the proportion of stunting

Figure 4 is the result of the Drought Vulnerability study per village and compared with nutritional status in the Borobudur District area. This analysis involved 3 parameters or indices consisting of NDVI, NDWI, and LST Index. The three parameter indices were analyzed using the Overlay Technique and utilizing the opensource GIS application, Quantum GIS. After each region shows a Drought Vulnerability status, it is followed by adding the percentage of nutritional status for children under five years old for each village region. The visualization results show the Drought Vulnerability status per village and the nutritional status of children [24].

The northern to central areas are areas with high Drought Vulnerability status, while the southern region is an area with low Drought Vulnerability. Karanganyar Village is a village whose area has high vulnerability to drought and next are Tuksongo, Wanurejo, Borobudur, Tanjungsari, Karangrejo, and Tegalarum villages. In areas with high drought vulnerability status, these are areas where the stunting status in children was above 10%, a figure which indicates that the area has children under five years old with low nutritional status in the Borobudur District area, except for Tuksongo Village which had a low percentage of stunting cases (5.8%). Several journals explain the relationship between drought and stunting vulnerability in an area [4, 25, 26].

Several villages with high stunting status were those with high drought vulnerability, such as Karanganyar Village (12.69% stunting) which is a village with high drought vulnerability. There were seven villages with high drought vulnerability values that have stunting status > 10%, these villages are Karanganyar Village (12.69%), Borobudur (12.58%), Wanurejo (10.58%), Karangrejo (11.88%), Tanjungsari (12.62%), Tegalarum (12.93%), Kembanglimus (21.54%), however there was one village with high drought status and low stunting status, Tuksongo (5.76%).

Table 1. Spatial indicators on drought vulnerabilities and average stunting prevalence of under-five years old children

Villages	Drought Vulnerability	Average of Stunting Prevalence
Karanganyar, Borobudur, Tuksongo, Wanurejo, Karangrejo, Tanjungsari, Tegalarum, Kembanglimus	High	12.57%
Bumiharjo, Candirejo, Ngadiharjo, Ngargogondo, Wringinputih, Giritengah	Moderat	8.93%
Giripurno, Kebonsari, Bigaran, Majaksingi, Sambeng, Kenalan	Low	8.73%

3.2.2 Statistical Analysis

Table. 2. Correlation between Spatial Drought Vulnerability Indicator and Stunting Prevalence

No	Variables	Categories	Mean ± SD	F	p value
1	Drought (overlay)	Low	8.733 ± 4.758	1.763	0.201
		Medium	8.933 ± 4.034		
		High	12.575 ± 4.310		
2	NDWI (water)	Low	13.388 ± 3.954a	4.620	0.025*
		Medium	9.540 ± 4.117		
		High	7.400 ± 3.573a		
3	NDVI (vegetation)	Low	12.086 ± 5.374	1.450	0.262
		Medium	8.129 ± 4.423		
		High	10.850 ± 2.969		
4	LST (temperature)	Low	9.157 ± 4.529	1.256	0.310
		Medium	12.750 ± 4.942		
		High	9.429 ± 4.004		

*Significant at $p<0.05$; [a]significant mean difference on post-hoc

The highest average percentage of stunting (12.575 ± 4.310) was in areas with high drought levels. While the mean percentage of stunting was almost the same between areas with low (8.733 ± 4.758) and medium drought levels (8.933 ± 4.034). Based on the result of the analysis, there was no difference in the percentage of stunting with the level of drought ($p>0.05$).

Based on the variable NDWI, the highest average percentage of stunting (13.388 ± 3.954) was in areas with the lowest water availability and the opposite, the lowest average percentage of stunting (7.400 ± 3.573) was in areas with high water availability. The p value ($p<0.05$) indicated that there was a difference in the percentage of stunting with water levels. The result of further analysis to determine which group was significantly related, it appearred that the group that was related was between low and high-water availability levels ($p<0.05$).

The average percentage of stunting was highest (12.086 ± 5.374) in areas with low vegetation levels followed by high vegetation areas (10.850 ± 2.969) and lowest at the medium vegetation level (8.129 ± 4.423). There was no difference in the percentage of stunting with the level of vegetation ($p>0.05$)

The highest average percentage of stunting was in areas with medium temperature levels (12.750 ± 4.942). While the mean percentage of stunting was almost the same between areas with low (9.157 ± 4.529) and high temperatures (9.429 ± 4.004). Based on the result of the statistical analysis, there was no difference in the percentage of stunting with the temperature level ($p>0.05$).

4 Discussion

This study found variations in the prevalence of stunting cases ranging from very low (Bumiharjo Village) to high (Kembanglimus Village) with Borobudur region-level prevalence of 10.2% (medium). This prevalence was lower than the stunting prevalence data at the Magelang district level based on both routine nutrition surveillance data sources and the results of the 2023 national survey, which were 13.9% [27] and 25.8% [28], respectively. Nonetheless, prevention strategies were still needed, considering that the magnitude of the problem was still in the medium category, and there were still villages with a high stunting problem category (>20%). Mapping the problem to the village level provides information on which areas need to be prioritised.

This research found that in the area with the low NDVI showed the highest rate for child stunting, but did not correlate significantly with the higher risk of stunting prevalence. This is different with research finding in Lake Victoria Basin area, Eastern Africa which found change in vegetation assessed with NDVI related could predict the prevalence of child malnutrition [29]. The different research result could come from different method due to limitation of this research, which used cross-sectional method. The NDVI assessment was conducted at Lake Victoria Base utilizing time series, allowing the vegetation change over time to be expressed and more responsive to the heightened malnutrition prevalence [29]. Similar result where NDVI not related with stunting were in research in several West African countries [30]. The research also concluded that NDVI more favorably linked with wasting than with stunting, which also demonstrate in research in Eastern Chad [30, 31]. NDVI also demonstrated a positive relationship with child survival and nutrition in nations with a wide range of NDVI values [30].

This study found the higher prevalent rate of child stunting among villages with high level of drought vulnerability. This research used overlay of three drought-prone spatial indicators of NDVI or vegetation index, NDWI, and LST. Due to previous research, these indicators are interrelated and have an impact on one another in the dynamics of drought condition. Massive regional development can trigger a decrease in the NDVI index due to reduced green open land. This condition will also trigger low water absorption into the soil which results in a decrease in the NDWI Index or lower water content in the soil which can ultimately trigger the emergence of the Urban Heat Island (UHI) phenomenon [32]. UHI is a phenomenon where the Land Surface Temperature (LST) of an area becomes higher than the surrounding area, resulting in the formation of a local low pressure air system. This change in air pressure can give rise to changes in wind patterns where the wind will tend to move from high pressure areas to low pressure areas [33,34]. Changes in wind patterns will affect local weather or local areas. The complexity increases when the NDVI index is low, NDWI is low, which will reduce the amount of vegetation in the area [35]. A decrease in vegetation will reduce the role of vegetation in the hydrological cycle [36], and will affect local humidity in the area. Changes in NDVI from high to low can influence a series of complex environmental changes such as changes in wind pressure and weather patterns. However, NDWI is not always influenced by the presence of vegetation, the height of the area above sea level can also influence the NDWI Index, areas at low altitude but surrounded by water-rich and high areas will retain water in the ground [37]. The complexity of a region's drought will be even more complicated if it has a low NDVI index and NDWI index, in which their changing condition can trigger an increase in land surface temperature [38]. The generate for high and low NDVI and NDWI can be caused by non-natural causes such as changes in the land use caused by regional development for regional economic reasons such as tourism [39, 40], which also found in Borobudur, which stated as super priority area for tourism destination development [41].

The composite spatial indicators of drought showed the trend for higher prevalence of stunting with the higher drought prevalence. Several villages with high stunting status are those with high drought vulnerability. In this research, this related to the availability of water source. This study found that areas with less water source (low NDWI) showed a trend of higher stunting. This result is in line with research in Ethiopia that shows a close relationship between drought conditions and the incidence of malnutrition [42]. The results of a systematic review of 27 studies concluded that toddlers from families with the lowest income were the most affected group experiencing malnutrition due to drought conditions [43]. The review also explained that the impact of drought on malnutrition has yet to be clearly measured depending on the context of a region. However, possible mechanisms that play a role in explaining the relationship between water availability and nutritional status include hygiene and sanitation conditions and family food security. Water availability is associated with poor hygiene and sanitation conditions that increase the risk of exposure to pathogenic bacteria that cause infectious diseases [44]. Infectious diseases such as diarrhea are a direct cause of malnutrition in children [45]. Food security and nutrition are the most discussed conditions as one of the impacts of drought due to climate change. Limited water availability can lead to crop failure and affect the nutritional intake of the family. If these conditions occur repeatedly, they will have an impact on the nutritional status of children, especially toddlers [46]. Research in India shows agricultural drought, related to the food source availability, is substantially associated with stunting [3].

Stunting manifests multiple factors, from health to social to economic [47]. A multi-stakeholder approach, supported by strong leadership, has proven to be an effective strategy in reducing stunting in countries with diverse geographical, financial, and social challenges. Village governments play an important role in reducing stunting among children under five [48]. A study found that village funds supported by good management capacity have a positive correlation with stunting reduction efforts in Indonesia [49]. Environmental factors can be important for child nutrition outcomes [29], therefore understanding how the drought-prone spatial analysis of environmental factors in a village level could play significant role in mitigating impact of drought in child health.

5 Conclusion

The average prevalence of stunting was higher in the areas with high, compared to medium, and low drought vulnerability, but not statistically significant. Stunting is significantly related to water source availability (NDWI). A lower NDWI index increases the risk of stunting in children. NDWI spatial analysis can be used as a reference to support preventive efforts to mitigate the impact of drought on the nutritional status of children in rural areas.

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