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Research article

Forecasting of diarrhea disease using ARIMA model in Kendari City, Southeast Sulawesi Province, Indonesia

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A R T I C L E I N F O

Keywords:
Incidence
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A B S T R A C T

Background: In Indonesia, diarrhea is one of the endemic diseases that often leads to death. The high number of diarrhea cases has the potential to become an extraordinary event, thus requiring more serious attention. This research aims to analyze the data on recorded cases of diarrhea in the Health Department of Kendari City from January 2016 to June 2022.
Methods: The ARIMA model, commonly referred to as ARIMA (p, d, q), is used, where *p* represents the autoregressive terms, *d* indicates the non-seasonal differences required for achieving stationarity, and *q* denotes the lagged forecast errors in the prediction equation. To determine the order of the autoregressive (AR) and moving average (MA) components included in the ARIMA model, the patterns of the plot of the auto-correlation function (ACF) and the partial auto-correlation function (PACF) were utilized. Data analysis was carried out using Minitab Release 16 software.
Results: The forecast using this model indicates a decrease in diarrhea cases over the next two years, from July 2022 to June 2024. The forecast estimates a total of 1.971 diarrhea cases from July 2022 to June 2023 and 1.255 cases from July 2023 to June 2024.
Conclusions: The incidence of diarrhea in Kendari City fluctuates every year. This forecast provides an early warning to the government to take preventive measures against diarrhea. It is hoped that this system will reduce the negative impact of diarrhea in Kendari City.

1. Introduction

Diarrhea is a significant global health concern that affects healthcare centers at all levels, from primary care to hospitals. It is concerning that this disease is responsible for the second-highest number of deaths in children under the age of 5, with an estimated 760.000 fatalities annually across all age groups. Developing countries, such as Afghanistan, India, Nigeria, Ethiopia, and Indonesia, are disproportionately affected by this disease [1].

Loose stools and frequent bowel movements are the primary symptoms of diarrhea [2,3]. For toddlers, having more than three bowel movements in a day is considered diarrhea, while for newborns, it's identified if they have more than four [4]. This medical condition is caused by viral, bacterial, or parasitic infections that invade the digestive system, with common culprits like norovirus, rotavirus, *Escherichia coli*, Salmonella, Campylobacter, Giardia, and Cryptosporidium [5,6]. In addition to biological factors, social factors like personal hygiene, environmental cleanliness, and food handling practices can also contribute to the occurrence of diarrhea [7,8].

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In Indonesia, diarrhea is a serious concern as it can rapidly escalate into an outbreak and even cause fatalities. In 2016, there were three outbreaks in three provinces, resulting in six deaths and 196 cases. In 2017, 12 provinces reported 21 outbreaks, leading to 34 deaths and 1.725 cases. The following year, eight provinces saw ten outbreaks, causing 36 deaths and 756 cases. The case fatality rate (CFR) during these outbreaks increased annually, with rates ranging from 3.03 % to 4.76 % [9].

Efforts are being made by the government to prevent and control diarrhea. These include establishing standardized policies for managing diarrhea in healthcare facilities, implementing surveillance systems to detect outbreaks early, and improving the knowledge and skills of healthcare workers in program management and technical aspects. Despite these efforts, diarrhea remains a significant public health concern, and its incidence remains relatively high in some areas of Indonesia [10–14].

Southeast Sulawesi, an eastern province in Indonesia, has been experiencing a persistent issue with diarrhea cases, causing concern among its residents. The Health Office of the province has released data that shows a consistently high number of cases. In 2016, 76.676 cases were reported, followed by 74.300 cases in 2017. In 2018, there were 31.886 cases, and 22.200 cases in 2019. The number rose to 34.195 cases in 2020 [9]. To effectively prevent and control diarrhea in Southeast Sulawesi, it's crucial to have a thorough understanding of its patterns and create models to forecast the disease.

In the COVID-19 pandemic era, the Ministry of Health of the Republic of Indonesia, through the 2018 Basic Health Research, reported that the prevalence of diarrhea across all age groups was 8 %, with the prevalence rate for children under five being 12.3 %. Meanwhile, the prevalence of diarrhea in infants was 10.6 %. According to the 2018 Sample Registration System, diarrhea remained one of the leading causes of death in neonates at 7 % and in infants aged 28 days at 6 %. Data from the Health Communication Data Center for the period of January–November 2021 indicated that diarrhea caused mortality in the post neonatal stage at 14 %. The latest data from the 2020 Indonesian Nutrition Status Survey showed that the prevalence of diarrhea was 9.8 %. Diarrhea is closely linked to the occurrence of stunting. Repeated diarrhea incidents in infants and toddlers can lead to stunting. According to the 2020 Indonesian Health Profile data, infectious diseases, especially diarrhea, were contributors to mortality in children aged 29 days to 11 months. As in the previous year, in 2020, diarrhea continued to be a major issue, causing 14.5 % of deaths. Among children under five (ages 12–59 months), diarrhea-related deaths were 4.55 % [15,16]. The objective of this study was to apply the ARIMA model to forecast the occurrence of diarrhea in Kendari, a city situated in the heart of Southeast Sulawesi Province, Indonesia.

2. Method

2.1. Study area

Kendari is a central city in Southeast Sulawesi Province, situated between 3°54′40″ and 4°5′05″ South Latitude, and spanning from west to east between 122°26′33″ and 122°39′14″ East Longitude. Kendari comprises 16 districts and covers a total area of 271.76 km^2, which is equivalent to 0.7 % of the entire province's area. As per the Central Statistics Agency's report in 2021, Kendari's population is 350.267, with a population density of 1289 per km^2 [17].

2.2. Data sources

The Kendari City Health Office's surveillance system has provided data on cases of diarrhea from 2016 to 2022. The data was gathered from the Community Health Center, where diarrhea patients receive treatment and their cases are recorded. Monthly reports on the data are sent to the Disease Prevention and Control section of the Kendari City Health Office, where they are validated according to the standards established by the Ministry of Health of the Republic of Indonesia. In Indonesia, patient care begins at primary health facilities known as Puskesmas (Community Health Centers). Puskesmas function as primary healthcare services responsible for providing basic medical care to the local community. As part of the national health system, Puskesmas manage and record disease data, including cases of diarrhea, occurring in their service areas. The data collected by Puskesmas is used to monitor public health and assist in planning and decision-making related to health interventions at local and national levels [18,19].

2.3. Case definition

Diarrhea was defined as the occurrence of three or more loose stools within a 24-h period or the presence of visible blood in one or more loose stools. The Ministry of Health of the Republic of Indonesia classifies diarrhea into four types: acute diarrhea, dysentery, persistent diarrhea, and diarrhea with additional complications. Acute diarrhea is characterized by a duration of less than 14 days (usually less than 7 days). Dysentery is a type of diarrhea that includes the presence of blood in the stool. Persistent diarrhea refers to diarrhea that lasts for more than 14 consecutive days. Finally, diarrhea with other problems refers to the condition where a child experiences diarrhea and may also exhibit other symptoms such as fever, nutritional disorders, or other illnesses [20].

2.4. Data analysis

The analysis of data was carried out through the utilization of Minitab Release 16 software. The ARIMA model is commonly referred to as ARIMA (p, d, q), where p represents the autoregressive terms, d indicates the non-seasonal differences required for achieving stationarity, and q denotes the lagged forecast errors in the prediction equation. To determine the order of autoregressive (AR) and moving average (MA) included in the ARIMA model, the patterns of the plot of the auto-correlation function (ACF) and the partial auto-correlation function (PACF) were utilized [21,22]. The steps in data analysis in the ARIMA as follows: First, time series graphs and the Dickey Fuller test are performed to find out whether the time series data is stationary. If not, logarithmic transformation or difference is done to achieve stability. Second, ARIMA models are established for a stationary time series, and the model with the minimum akaike information criterion (AIC) and schwartz bayesian information criterion (SBC) values is considered the optimal model. The model parameters are then estimated using the conditional least squares method. The third stage is to verify the adequacy of the ARIMA model. A Box-Ljung test is conducted to check whether the residual series is a white noise sequence. A white noise sequence is a purely random time series without an autocorrelation, and useful information has been extracted from the sequence for model fitting. If not, the model must be re-established. Finally, a prospective prediction is conducted using the optimal model which was applied to predict the infectious diarrhea incidence. Forecasting data will be evaluated to determine the level of accuracy of forecast results by looking at the mean absolute percentage error (MAPE) and mean absolute deviation (MAD). The capacity of a model to predict data that it has never seen before—not merely the data used to train the model—is known as out-of-sample predictive validity. This is crucial because it prevents overfitting, evaluates the model's effectiveness on fresh data, and gives a more accurate representation of the model's behavior in actual scenarios.

2.5. Ethics consideration

The research project received ethical approval from the Research Ethics Committee of the Indonesian Public Health Association in Southeast Sulawesi Province. The approval number was 101/KEPK-IAKMI/II/2022 (see Fig. 1).

3. Results

3.1. Model identification for diarrhea

The monthly diarrhea incidence from January 2016 to June 2022 in Kendari was between 954 and 3.863, with an incidence rate between 4.77 and 164.32/100.000 inhabitants. Fig. 2a displays the occurrences of diarrhea over the past six years. Meanwhile, Fig. 2b shows the monthly incidence of diarrhea which does not exhibit a distinct pattern. As seen in the figure, the incidence of diarrhea fluctuates significantly. Data indicates that while the incidence rate varies, January typically marks the peak of diarrhea episodes. This could be the result of a number of things, including local behavioral patterns, the weather, and other environmental elements that can influence the spread of diarrhea in that particular month.

3.2. Parameter estimation

After obtaining the tentative ARIMA model, the next step was to estimate the parameter values of the AR and MA coefficients for

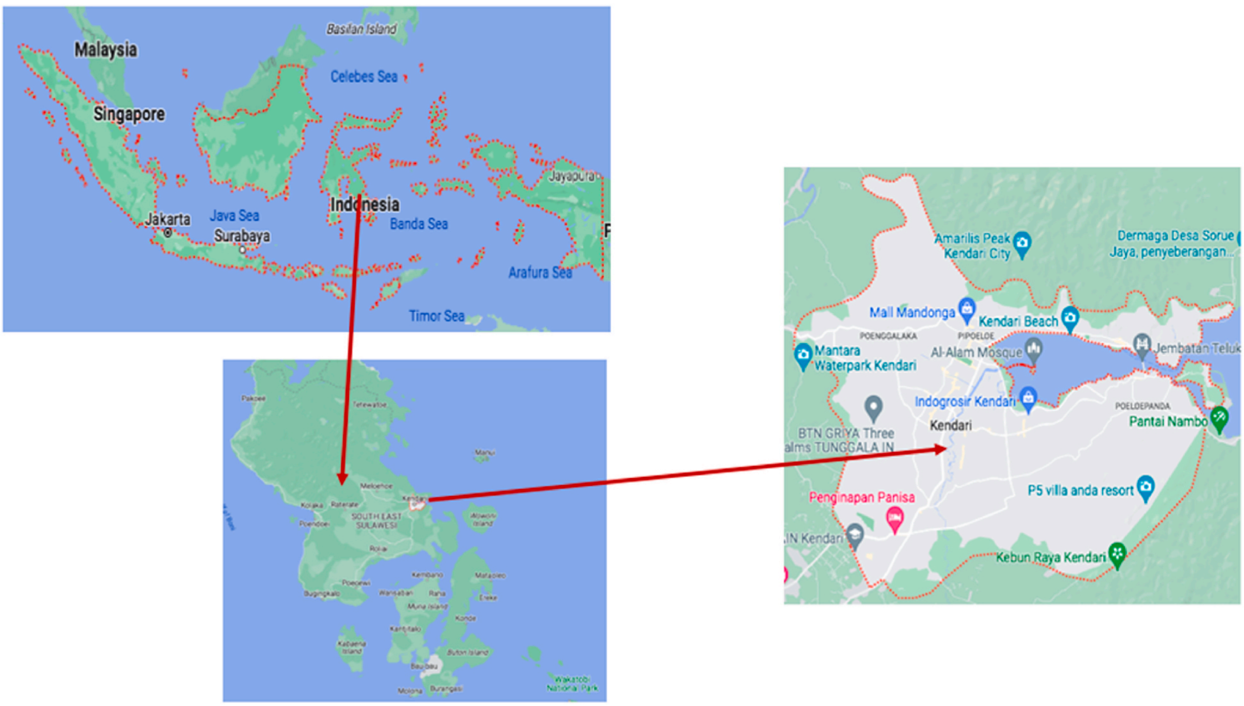

Fig. 1. The geolocation of Kendari City in Southeast Sulawesi Province, Indonesia (map was created with Google map, access on June 14, 2022.

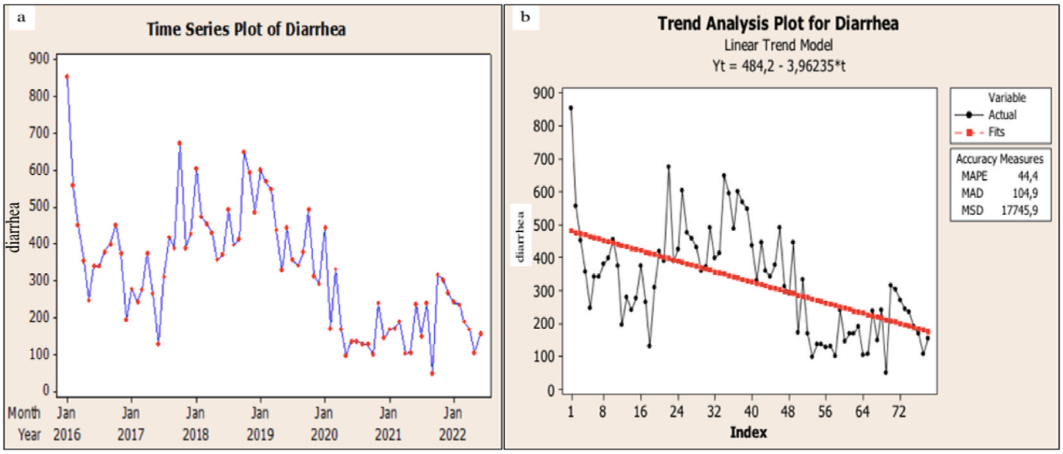

Fig. 2a. Plot of Diarrhea incidence from January 2016 to June 2022 in Kendari City. Trend Analysis of Diarrhea incidence from January 2016 to June 2022 in Kendari City.

each parameter in the model. This was performed to evaluate whether these parameters were significant and should be included in the model. The parameter estimation criteria involves checking whether the p-value is less than $\alpha = 0.05$ at a 95 % confidence level.

3.3. Diagnostic checking

Diagnostic checking involves conducting tests for white noise and normality. To assess the presence of white noise in the model, the Ljung-Box test is commonly used. The assumption of white noise is satisfied when the significance level obtained from the Ljung-Box test is greater than α, where α is typically set at 0.05. The results of diagnostic checking were reported in Table 1. For the lag models ARIMA (1,1,0) and (0,1,1) at lags 12, 24, 36 and 48, the *p-value* was less than α (0.05). This implied that the ARIMA (1,1,0) and (0,1,1) models were not considered white noise (residuals were noted between lags 12, 24, 36 and 48). On the other hand, for the ARIMA (1,1,1) model, the *p-value* for lags 12, 24, 36 and 48 was greater than 0.05, indicating that the model (1,1,1) was already considered white noise.

3.4. Best model for forecasting

The final stage of the research utilized the best ARIMA model, specifically ARIMA (1,1,1), which had passed the validation tests to forecast the number of diarrhea cases in Kendari City from July 2022 to June 2024. Table 2 presents the forecast results for the number of diarrhea cases for the period of July 2022 to July 2024, comprising a total of 24 data points. The forecast indicates a decline in the number of diarrhea cases in the future. The model was then evaluated to assess the forecasting error, using 78 historical data points from January 2016 to June 2022. The MAPE (Mean Absolute Percentage Error) value obtained was 46 %, while the MAD (Mean Absolute Deviation) was 4.95. MAPE measures the percentage of absolute error between actual data and projected data, while MAD represents the average absolute deviation between the actual and forecasted data.

In Fig. 3, the trend of diarrheal cases forecasted from July 2022 to June 2024 is visible. The trend data indicates a decrease in diarrheal cases over the next two years. Based on this trend analysis, no indications appear of an outbreak for diarrheal disease in the next two years, however, maintaining vigilance regarding case occurrences remains important by taking early preventive measures to prevent a significant increase in cases and avoid fatalities.

Table 1
Ljung-Box test results for estimated parameters of the ARIMA model.

Lag	12	24	36	48	Results
Model (1,1,0)					
Chi-square	38.4	54.2	68.1	79.7	*Not white Noise*
P-Value	0.000	0.000	0.000	0.001	
Model (0,1,1)					
Chi-square	25.1	41.9	51.8	62.0	*Not white Noise*
P-Value	0.005	0.006	0.026	0.057	
Model (1,1,1)					
Chi-square	13.6	26.9	40.3	47.0	*White Noise*
P-Value	0.138	0.175	0.177	0.391	

Table 2
Diarrhea case forecast July 2022–June 2024.

Months	Forecasting 2022	Months	Forecasting 2024
July	227	July	94
August	180	August	121
September	132	September	72
October	287	October	153
November	231	November	170
December	173	December	113
January	248	January	188
February	161	February	102
March	162	March	102
April	108	April	48
May	41	May	−18
June	95	June	36

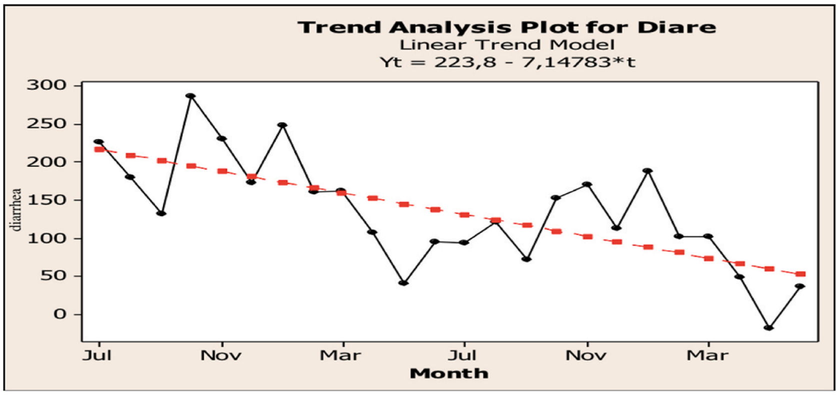

Fig. 3. Analysis Trend of Diarrhea incidence from July 2022–July 2024.

4. Discussion

The forecast of diarrheal cases in Kendari City was performed using the Box-Jenkins method, also known as the ARIMA method. The plot of the original data for diarrheal cases in Kendari City shows fluctuating ups and downs. Visually, the data does not exhibit stationary properties, which is a prerequisite for time series data forecasting using ARIMA. Therefore, it became necessary to transform the data to stationary in terms of variance and use a differencing process to make the data stationary in terms of the mean.

Based on the data from the Kendari City Health Department over the past six years (2016–2021), diarrheal cases have experienced fluctuations. In 2016, a total of 4.943 cases decreased to 4.170 cases in 2017. In 2018, a drastic increase to 5.730 cases was noted, but it decreased again in 2020 to 2.227 cases. In 2021, an increase to 2.291 cases was observed. Based on the forecast results, in 2022, the number of diarrheal cases in Kendari City is expected to decrease to 2.250 cases, while in 2023, it has been predicted to total 1.612 cases. Although no seasonal patterns were found in the occurrence of diarrhea in Kendari City based on the research results, it became known that the highest number of cases typically occurs in October and January. Several factors can influence the increase and decrease of diarrheal cases including hygiene practices, household environmental conditions, waste disposal and wastewater management as well as weather factors. Temperature variations, rainfall and humidity can affect pathogen resistance, virulence, transportation and exposure patterns among hosts. One of the factors contributing to the high incidence of diarrheal cases is climate change.

In this forecast, the highest number of diarrheal cases occurs in October, coinciding with unpredictable weather anomalies. This can impact environmental conditions and increase the proliferation of disease vectors. Climate change also has implications for human health, as air temperature, rainfall and humidity can contribute to diarrheal diseases. Climate change greatly influences unsanitary environmental conditions and the lack of attention to food hygiene. During climate change, parasites, viruses and disease vectors can multiply rapidly.

Weather factors also play a role in transmitting infectious diseases including diarrhea. The rainy season, especially during floods, is associated with an increased incidence of diarrheal diseases. The dry season is also linked to the occurrence of diarrheal diseases. High rainfall can cause floods and contaminate water supplies, while low rainfall can lead to a lack of clean water supply, which has adverse effects on food sanitation and the environment. The availability of clean water and the sanitation conditions in one area are influenced by the availability of water resources and the potential for floods and droughts [23].

The different causes of diarrhea are referred to as the etiology of diarrhea. An increase in the frequency of bowel movements along with a more liquid quality of feces is the hallmark of diarrhea. Infections with bacteria, viruses, or parasites; lactose intolerance; food allergies; celiac disease; irritable bowel syndrome; inflammatory bowel disease; pancreatitis; tainted food and water; and inadequate hygiene are the primary causes of diarrhea [24–27].

The COVID-19 pandemic has had an impact on a number of public health issues, notably Indonesia's diarrheal illness rate. Patients suffering from diarrhea might not have been able to get the care they needed during the epidemic because of movement restrictions and the prioritizing of COVID-19 treatment. Fear of contracting COVID-19 caused many people to stay away from medical institutions, which may have reduced the number of instances of diarrhea that are identified and treated. Medical workers and other health resources were focused on treating COVID-19 cases, which may have resulted in less attention and funding being allocated to other illnesses like diarrhea. Furthermore, it's possible that during the epidemic, fewer cases of other infectious disorders were being monitored and reported, such as diarrhea [28–30].

The identified relationship between diarrheal incidence and climate variables highlights the importance of raising public awareness about environmental hygiene and practicing hygienic behaviors, especially during the peak rainy and dry seasons. Educating and encouraging the community members to maintain cleanliness in their surroundings and adopt hygienic practices to prevent diarrheal diseases is crucial. Through such cooperative actions, individuals can mitigate the risks associated with climate-related factors and contribute to maintaining a healthier environment [31]. In addition to climate conditions, many other risk factors are believed to contribute to the occurrence of diarrheal diseases [32,33]. Some of these factors include poor environmental sanitation, unhygienic water supplies and lack of knowledge [34]. Poor personal hygiene practices, such as inadequate handwashing and lack of proper toilet facilities, can also lead to diarrheal diseases [35]. Diarrhea can be caused by viruses, bacteria and parasites with the majority of cases being caused by pathogens such as viruses and bacteria [26,36]. Disease transmission occurs through the fecal-oral route, primarily through contaminated water, serving as the main medium of transmission [37,38]. Diarrhea can occur when a person consumes contaminated drinking water, whether from the source, during the water distribution process to households, or when it becomes contaminated during storage at home [39,40]. The risk of diarrhea can also arise when a person consumes food contaminated by animals such as flies carrying viruses or bacteria from feces in significant amounts [41,42]. Furthermore, poorly stored and easily contaminated food can also trigger diarrhea [43,44]. Failure to wash hands before and after cooking, eating and after using the toilet can directly contribute to contamination [45,46].

Food sanitation significantly impacts the occurrence of diarrhea [47]. This research finding is also supported by Nurhaedah's study, reporting a significant relationship between the use of clean water, household toilets, household waste management and wastewater disposal facilities with the occurrence of diarrhea. Food sanitation is an effort aimed at ensuring food safety with the goal of breaking the chain of transmission of microorganisms that are the source of foodborne diseases [48]. Factors contributing to the decrease in diarrhea cases include public awareness of the importance of hygiene, sanitation and attention to personal cleanliness and the surrounding environment [34,49]. Additionally, programs conducted by healthcare institutions to help eradicate communicable diseases play a crucial role. This includes government programs focusing on building toilets for economically disadvantaged communities to reduce open defecation. Moreover, implementing rapid response programs or early warning systems for diseases also contributes to the swift management of diarrhea cases and reduces the risk of wider transmission.

The research conducted by Menik Samiyati et al. (2019) showed a relationship between toilet conditions and the occurrence of diarrhea among toddlers. This was revealed by the p-value (0.010) being smaller than α (0.05), indicating a significant relationship. Additionally, toilet conditions are also identified as a risk factor for diarrhea among toddlers, as indicated by the lower value in the Relative Risk (95 % CI) being greater than 1, specifically 2.900 (1.413–5.950) [50]. The obtained forecasting results are expected to contribute to efforts in addressing and preventing diarrhea cases in Kendari City. Although forecasting results cannot guarantee complete accuracy regarding future cases, the information is crucial in the planning process of diarrhea prevention programs. It helps in making informed decisions and designing effective strategies to combat the disease. Some of the measures taken to prevent the occurrence of diarrhea include offering rotavirus vaccinations to prevent diarrhea caused by rotavirus infection, especially in children, enhancing community access to clean water and adequate sanitation facilities, promoting clean and healthy living practices like washing hands with soap, and organizing public awareness campaigns about the causes, prevention, and treatment of diarrhea.

5. Limitations

The weaknesses in research related to predicting diarrhea cases include several aspects. First, the study does not utilize the most recent data from 2023, even though data from that year is important for understanding current trends in diarrhea. The latest data can provide a more accurate picture of the current situation and help make more relevant predictions. Additionally, there is a methodological weakness in this study because it does not include covariates in the prediction model. Therefore, future similar studies should consider including covariates in the prediction model.

6. Conclusion

The incidence of diarrhea in the Kendari City fluctuates every year. This forecasting provides early warning to the government to take preventive actions against diarrhea. The system is expected to reduce the negative impact of diarrhea in Kendari City. In efforts to eradicate and minimize diarrhea cases, regular surveillance of diarrhea should be conducted on a monthly basis. This allows for continuous monitoring of diarrhea cases, identifying changes in trends and patterns that may occur. Additionally, collaboration with relevant sectors is crucial in preventing diarrhea outbreaks. Collaboration among various sectors, such as health, sanitation, education and the community, can enhance the effectiveness of prevention and control efforts for diarrhea. With regular surveillance and intersectoral cooperation, prompt and appropriate actions can be taken in addressing diarrhea cases including preventing outbreaks.

CRediT authorship contribution statement

Ramadhan Tosepu: Writing – review & editing, Writing – original draft, Validation, Conceptualization. **Neneng Yulia Ningsi:** Project administration, Investigation, Data curation.

Data availability

Data will be made available on request.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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