Forecasting of Tropical Climate Using Integration on Mann Kendall Test and ARIMA Model for Production of Rice Husk Particle Board

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Forecasting of Tropical Climate Using Integration on Mann Kendall Test and ARIMA Model

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Abstract: *Climate change became global concerns. This research analyzes climatic trends and forecasting future changes by including 30 years (1995 - 2024) of historical climate data. The Auto Regressive Integrated Moving Average (ARIMA) model utilized to forecast climate trends, while the Mann-Kendall test and Sen's slope estimator for identifying and measuring monotonic trends in temperature and precipitation. Results reveals mean annual rainfall 2,653.97 mm, with range of 1,614.2 mm (2016) to 3,931.2 mm (2014). The mean temperature 26.8°C, with a range of 25.8°C to 27.9°C. Both rainfall and temperature showed non-significant downward trends (–7.724 mm/year, p = 0.643 and –0.011°C/year, p = 0.335, respectively), indicating minimal long-term change during the period. Based on ARIMA model forecasting, temperatures gradually rise from 27.7°C (2025) to 28.3°C (2050), while rainfall continue fluctuate between 2,391 and 2,627 mm. This research highlights proactive climate adaptation strategies needed to protect environmental resources for future generations.*

Keywords: ARIMA Model, Climate Trend Analysis, Mann Kendall Test, Rainfall and Temperature

1. INTRODUCTION

Climate change known as gradual changing of rainfall, temperature, weather changes and other climatic factors [1]. The changes pose threats towards public health, water resources, biodiversity, and infrastructure, particularly in vulnerable areas. Temperature and rainfall are the two main climatic factors that directly affect ecosystem stability while also reflecting larger environmental changes [2]. The Intergovernmental Panel on Climate Change (IPCC) estimates that there is a more than 50% chance that, under all observed scenarios, global temperatures will rise by 1.5 degrees Celsius or more between 2021 and 2040 [3].

In Malaysia, climate variability has risen in recent decades, with noticeable shifts in rising mean temperatures and monsoonal patterns [4]. Among the worst in the nation's history, the 2014 Kelantan floods were one significant incident that caused over 100,000 people to be relocated and seriously damaged infrastructure in areas like Gua Musang [5,6]. One of the main causes of this disaster was the northeast monsoon's heavy rainfall, in addition to human activities which highlights the effects of shifting climate extremes. Additionally, this flood occurrence revealed weaknesses in flood mitigation and urban drainage systems as well as land cover changes which directly influence biodiversity and fuel climate change [7,8] in addition to raising the danger of flooding highlighting the necessity of proactive climate analysis at the local level.

Nevertheless, there are still few long-term studies looking at rainfall and temperature patterns in the interior parts of Kelantan. Gua Musang, specifically, demonstrates an insufficiently researched yet climate-sensitive area because to its topography, forest coverage, and accessibility to river systems. This study utilizes the Mann-Kendall trend test and Sen's slope estimator, two well-known non-parametric techniques for identifying monotonic patterns in time series data, to examine trends in temperature and rainfall over 30 years of historical data (1995–2024). Furthermore, the Autoregressive Integrated Moving Average (ARIMA) model is used to predict future climatic behavior until 2040, providing estimates that are crucial for environmental planning and catastrophe preparedness. Analyzing trends in temperature and rainfall helps to mitigate the effects of climate change and, consequently, helps to identify solutions for urban drainage management systems [9].

The findings of this study have a direct impact on planning for climate adaptation, especially in the domains of hydrological management and environmental engineering. On the other hand, this research offers a scientific foundation for decisions about land use and climate-resilient infrastructure by detecting historical patterns and forecasting future climate conditions. These research support well-informed, data-driven plans for improving regional sustainability and resilience, which is in line with the Sustainable Development Goals (SDGs), especially SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). This study contributes to global frameworks for climate action while also advancing local understanding of climate dynamics, promoting sustainability for future generations.

2. MATERIALS AND METHODOLOGY

2.1 Study Area

Nenggiri, Gua Musang is located at Kelantan's southern region and is one of the state's largest districts in terms of land area (Figure 1). The district is situated between latitudes 4°45′N and 5°15′N and longitudes 101°45′E and 102°15′E. It is distinguished by its sloping topography, thick forest cover, and river network, which includes tributaries of the Nenggiri River. The rainfall patterns are greatly influenced by the two main monsoonal seasons, the northeast monsoon (November to March) and the southwest monsoon (May to September), which occur within the tropical rainforest climate zone. The area has more than 2,500 mm of rain on average every year, with the northeast monsoon bringing the highest levels of precipitation [10]. The temperature typically changes throughout the year, ranging from 22°C to 33°C. Gua Musang's hydrological and geographic characteristics make it extremely susceptible to severe weather events like landslides and floods. Additionally, the district is home to a number of rural and indigenous communities that are directly impacted by climate shifts and rely significantly on natural resources.

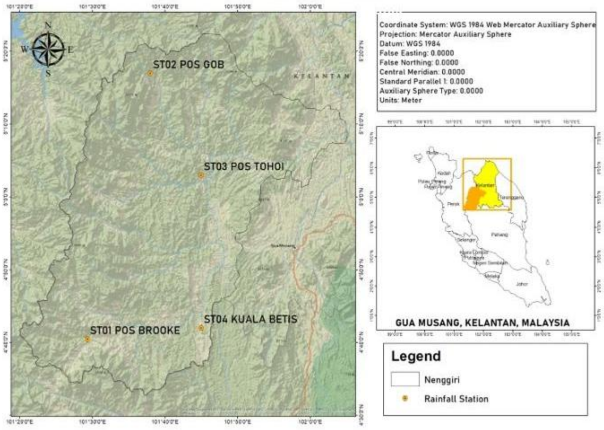

Fig 1. The study area, Gua Musang.

2.2 Data Collection

This study focused on long-term changes in temperature and rainfall utilizing secondary climate data from the Malaysian Meteorological Department (MetMalaysia). Specifically, the data contains observations from weather stations in Kelantan's Gua Musang area and spans a continuous 30-year period from 1995 to 2024. The variables used, monthly temperature (°C) and monthly rainfall (mm), are important measures of climate variability and have been utilized extensively in evaluations of regional climate trends. The dataset was checked for consistency and completeness to make sure there were no notable anomalies or gaps that might compromise the reliability of the statistical tests. Monthly and annual aggregates were calculated to assist with recognize trends over a climatologically relevant timescale. This 30-year period meets the World Meteorological Organization's (WMO) standard for climate trend analysis and enables a thorough evaluation of decadal-scale fluctuations [11]. These datasets serve as the empirical basis for the trend analysis and forecasting techniques used in the next sections, such as ARIMA modeling, Sen's slope estimator, and Mann-Kendall test.

2.3 Mann-Kendall and Sen Slope Analysis

The Mann-Kendall (MK) trend test and Sen's slope estimator were used throughout this study to examine at long-term trends in temperature and rainfall data. The Mann Kendall tests were used to determine the significance of the shift, while Sen's slope method was employed to quantify the rate of change in the rainfall indices [12]. The capacity to handle non-normally distributed data makes both non-parametric statistical approaches popular in hydrological and climatic time series analysis [13]. The Mann-Kendall tests detected the presence of monotonic trend over time. The MK statistic S calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i)$$

(Eq 1)

where the following defines the sign function:

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} +1 & \text{if } x_j - x_i > 0 \\ 0 & \text{if } x_j - x_i = 0 \\ -1 & \text{if } x_j - x_i < 0 \end{cases}$$

(Eq 2)

When S has a positive number, it shows an upward or increasing trend, while a negative value suggests a downward or declining trend. When n is fewer than 9, the absolute value of S is directly compared with Mann and Kendall's theoretical S distribution [14]. If n is at least 10 or more, the test has a normal distribution, then the normal approximation test is employed with the expectation (E) and variance of S VAR(S) as shown in Eq. (3). The variance then computed as:

$$V(S) = \frac{n(n-1)(2n+5) - \sum t_p(t_p - 1)(2t_p + 5)}{18}$$

(Eq 3)

Here, tp is the number of data points in the dataset's p^{th} tied group, and q is the number of tied groups. Equation 4 is used to compute the standardized test statistic (Z) in determine the significance of the trend.

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases}$$

(Eq 4)

The Mann-Kendall test statistic, which has a traditional normal distribution with a mean of 0 and variation of 1, is represented by the value Z. At a 95% confidence level, the trend is statistically significant if the absolute value $Z > 1.96$.

Sen's slope estimator, which has been calculated using the Theil-Sen estimator, is the slope of the linear trend. The trend's size is estimated using the Sen's slope estimator. It determines the median of any pairwise slope between time series data points that could exist.

Moreover, It is a nonparametric method for figuring out a trend's actual slope when it can be assumed that the trend is linear (as change with time). Equation 5 determines the slope (Q) estimations of N data pairs:

$$Q = median\left(\frac{x_j - x_i}{j - i}\right), \quad for\ all\ i < j$$

(Eq 5)

where x_j and x_i represent the data values at times j and i, respectively ($j > i$). The slope's Sen's estimator is the median of these N values of Q. The slope Q, which is measured in mm/year for rainfall or °C/year for temperature, indicates the annual rate of change. All the Mann Kendall and Sen Slope equation mentioned above were according to [15,16].

XLSTAT, a sophisticated statistical add-on software for Microsoft Excel, was used for this analysis, with assistance from the R packages "trend" and "Kendall." R was utilized for result validation and visualization, while XLSTAT was utilized for initial data handling and MK/Sen slope computation because of its intuitive interface.

2.4 Prediction using ARIMA Model

The Auto-Regressive Integrated Moving Average (ARIMA) is a model to analyze and forecast equally spaced univariate time series data, transfer function data, and intervention data [17]. Three main components of ARIMA including AutoRegressive (AR), Integrated (I), and Moving Average (MA) for identifying the patterns and trends in historical data. The model is highly useful for univariate forecasting of variables such as rainfall and temperature, especially when long-term data is available and seasonal influences exist. The ARIMA model was developed using IBM-SPSS version 20 and approaches on Box-Jenkins' algorithm method. The ARIMA model is expressed as:

$$Y_t = c + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

Where Y_t is time series value, c constant, ϕ_i are parameter for the autoregressive part (AR), θj are parameters for moving average part (MA), ε_t is white noise error, p, number of AR d is the degree of differencing, and q is the number of MA. The values of the ARIMA parameters (p, d, and q) for AR and MA are determined by evaluating the behavior of the Autocorrelation Function (ACF) and the Partial Autocorrelation Function (PACF). These functions play an important role in predicting the parameters used to forecast data using the ARIMA model.

3. RESULTS AND DISCUSSION

3.1 Trend of Rainfall and Temperature

The annual average rainfall for Nenggiri was shown in figure 2. The time series of annual rainfall display that the minimum rainfall recorded were 1614.2 mm in 2016 while maximum rainfall recorded were 3931.2 mm in 2014 with mean rainfall value were 2653.97 mm. Concurrently, figure X displayed the annual temperature for Nenggiri. The mean temperature was 26.8°C with minimum and maximum temperature were at 25.8 °C and 27.9°C respectively (as display in figure 3). The result indicates a large inter-annual variability in precipitation patterns across the research period, which might be related to both broader climatic changes and localized meteorological factors. Remarkably, the Gua Musang district, which includes the Nenggiri region, experienced a devastating flood disaster in 2014, which also recorded to be the year with the highest annual rainfall. Known variously as the "Bah Kuning" or "Yellow Flood," this catastrophe was one of the worst in recent Malaysian history, causing widespread infrastructure damage and forcing tens of thousands of people to relocate [18]. This correlation emphasizes the relationship between excessive rainfall and socio-environmental disturbance. Besides, these climate variations endanger livelihoods, food security, and infrastructure for residents in Nenggiri, particularly those dependent on agricultural and riverine ecosystems. The MK test' analysis of the annual rainfall and temperature revealed a non - significant decreasing trends in both rainfall and temperature.

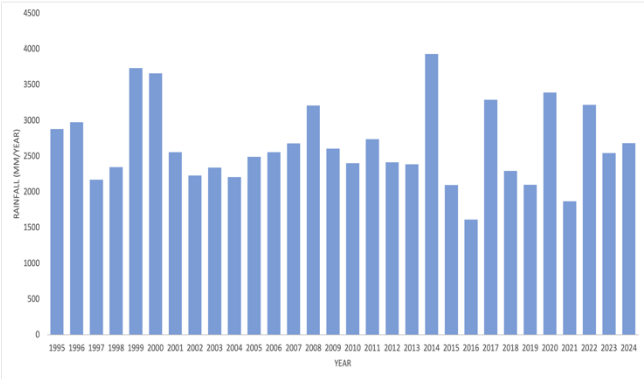

Fig 2. The annual rainfall of Nenggiri, Gua Musang (1995 - 2024)

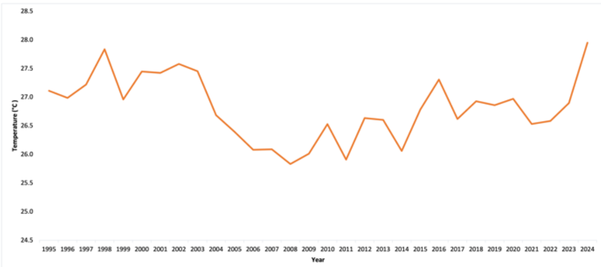

Fig 3. The annual temperature of Nenggiri, Gua Musang (1995 - 2024)

3.2 Mann Kendall and Sen Slope Trend (MK-SS) Analysis

The Mann-Kendall test showed that the slight decline in yearly rainfall (-7.724 mm/year) suggested by the Sen's slope analysis is not statistically significant ($\tau = -0.062$, $p = 0.643 > 0.05$). Moreover, the Mann-Kendall Z-statistic was found to be around -0.464, which is acceptable at the 5% significance level ($|Z| < 1.96$). As a result, there is no significant monotonic trend in yearly rainfall over the observed period at Nenggiri. Similarly, the Mann-Kendall test also showed no significant trend for yearly temperature, with a Kendall's tau of -0.126, a Z-statistic of -0.963, and a p-value of 0.335. With a 95% confidence interval between -0.038 and 0.021 °C/year, the Sen's slope was calculated to be -0.011 °C/year. Table 1 tabulate the Mann Kendall and Sen Slope trend for rainfall and temperature in Nenggiri. Overall, both rainfall and temperature in Nenggiri shown non-significant trends within the 30 years period (1995 - 2024). Similar research conducted in tropical areas has similarly revealed weak or flat monotonic trends as a result of the overlapping effects of land-use change, monsoon variability, and El Niño-Southern Oscillation (ENSO) cycles [19, 20]. Even though the slope estimates showed some modest decreasing trends, the Mann-Kendall Z-statistics and confidence intervals showed that these trends were not statistically significant. A non-significant trend does not necessarily indicate minimal risk for local authorities rather, it highlights the necessity of event-based planning rather than depending solely on long-term averages.

Table 1. MK-SS analysis for rainfall and temperature

Parameters	Rainfall	Temperature
Kendall's Tau (τ)	-0.062	-0.126
S Statistic	-27.000	-55.000
Var (S)	3141.667	3141.667
Z-Statistic	-0.464	-0.963
p-value (two tailed)	0.643	0.335
Sen's slope	-7.724 mm/year	-0.011 °C/year
Lower bound 95% (Slope)	[-29.464, 17.263] mm/year	[-0.038, 0.021] °C/year
Intercept	18,030.141 mm	48.021 °C
Upper bound 95% (Slope)	[-7,047.438, 39,872.068] mm	[15.927, 75.159] °C
Significance Level (α)	0.05	0.05

3.3 Time Series Forecasting Using ARIMA Model (1995 - 2050)

The forecasting of future annual rainfall and annual temperature was using the Auto-Regressive Integrated Moving Average (ARIMA) model, specifically the ARIMA (1,1,0) as illustrated in figure 4 and 5. The model's performance and residual diagnostics were taken into consideration when determining it. For each example, several statistical metrics such as as the Ljung-Box Q-statistic for autocorrelation in residuals, the stationary R-squared (Stationary R^2), regular R-squared (R^2), and root mean square error (RMSE) were employed to assess the model's accuracy. Table 2 summarizes the ARIMA model fit indicators and provides forecast statistics for both variables, including mean, min/max, and percentiles. Moreover, the ARIMA model statistics for annual rainfall and temperature (1995 - 2050) was tabulated in table 3.

The forecasted annual rainfall showed the ARIMA model had a Stationary R^2 value of 0.205, indicating limited explanatory power after differencing. The R^2 score of -0.86 indicates inadequate predictability due to high variability in the rainfall time series. The model's root mean square root (RMSE) was 787.71 mm, indicating significant changes in annual rainfall data. The Ljung-Box Q(18) value was 29.812 (p = 0.028), indicating the presence of residual autocorrelation, which could reduce the model's precision over longer time periods. The 1995–2050 rainfall projection showed an average of 2,508.81 mm, with a minimum of 2,391 mm expected in 2050 and a maximum of 2,626.93 mm in 2026. All forecast intervals showed consistent percentile estimates, indicating a steady trend in the ARIMA model's outputs. Despite this variability, the model predicts that rainfall patterns through 2050 won't drastically change or diverge. These findings are in line with research conducted in comparable tropical regions, where seasonal and localized climatic drivers continue to cause extremely varied rainfall patterns [21, 22].

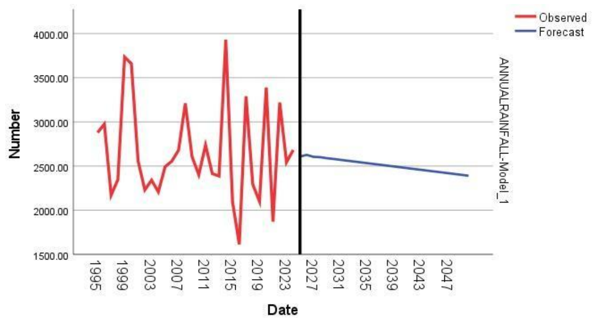

Fig 4. The forecasting and observed of annual rainfall values at Nenggiri, Gua Musang (1995 - 2050).

In contrast, forecasted annual temperature present the ARIMA model yielded a Stationary R^2 of 0.066 and a Regular R^2 of 0.328, showing a modest fit and minimal explanatory power, which is predicted given the region's relatively steady temperature changes. The RMSE was 0.478 °C, indicating that the forecast errors were minor and appropriate for climate data modeling. Residual diagnostics revealed that the Ljung-Box Q(18) statistic was 9.638 with a p-value of 0.918, indicating that the residuals were uncorrelated and the model fit was statistically valid. Throughout the simulated period (1995 - 2050), the average temperature was anticipated to be 28.03°C, with a minimum of 27.7°C in 2025 and a maximum of 28.3°C in 2050. The average yearly temperature of Malaysia is normally between 25°C and 28°C, with a persistently warm and humid tropical climate [23]. These forecasts indicate a gradual increase in temperature, which is consistent with the global climate change trends in Southeast Asia [24, 25]. Reported by [26], due to its distinct geographic and socioeconomic features, South Asia is particularly vulnerable to the effects of climate change, such as an increase in extreme weather events and changes in monsoon patterns.

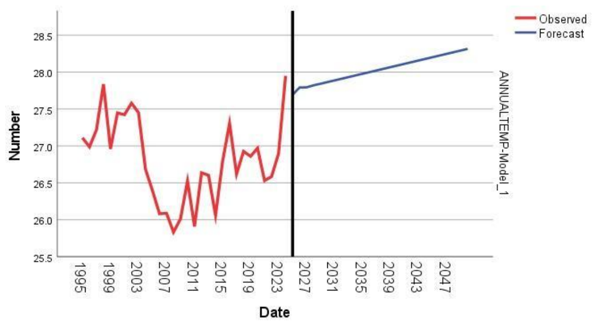

Fig 5. The forecasting and observed annual temperature values at Nenggiri, Gua Musang (1995 - 2050).

Table 2. The ARIMA model fit for annual rainfall and temperature (1995 - 2050)

Model	Fit Statistic	Mean	Min	Max	Percentile						
					5	10	25	50	75	90	95
Rainfall	Stationary R^2	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
	R^2	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86
	RMSE	787.71	787.71	787.71	787.71	787.71	787.71	787.71	787.71	787.71	787.71
Temperature	Stationary R2	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
	R2	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328
	RMSE	0.478	0.478	0.478	0.478	0.478	0.478	0.478	0.478	0.478	0.478

Table 3. The ARIMA model statistics for annual rainfall and temperature (1995 - 2050)

Model	No of predictors	Model fit statistics Stationary R^2	Ljung-Box Q(18) Statistics	DF	Sig	Numbers of outliers
Annual Rainfall	0	0.205	29.812	17	0.028	0
Annual Temp	0	0.066	9.638	17	0.918	0

Overall, the ARIMA-based predictions show that the trend for temperature is significantly increase, while rainfall is predicted to stay unpredictable without showing a clear long-term trend. The variation underscores the growing impact of global warming on local temperature regimes, while precipitation patterns are more unpredictable. These findings highlight the necessity of localized adaptation measures, especially in sectors like agriculture and water resource management, which are extremely sensitive to both temperature rise and rainfall variability. To overcome these challenges, proactive initiatives such as increasing irrigation efficiency, establishing agro-climatic zoning, and investing in weather-resistant infrastructure are required. In addition, incorporating climate forecasting methods into local planning and early warning systems can improve preparedness and lessen long-term socioeconomic risks in the Nenggiri area.

4. CONCLUSIONS

This research evaluated long-term climate patterns and future estimates in Nenggiri, Kelantan, utilizing a 30-year dataset (1995-2024) and forecasting models that extended to 2050. Furthermore, Mann-Kendall and Sen's slope analysis found no significant decreasing trends for yearly rainfall -7.724 mm/year or temperature -0.011 °C/year, indicating that previous climatic changes remained relatively stable with non-monotonic trends. The Auto-Regressive Integrated Moving Average (ARIMA) model forecasts a modest temperature increase from 27.7 °C in 2025 to 28.3 °C in 2050, with mild rainfall fluctuations 2,391-2,627 mm. These forecasts emphasize the possibility of greater thermal stress on ecosystems and communities and are consistent with larger trends in global warming. The anticipated warming highlights the necessity of local-scale climate adaptation measures, even though no notable historical changes were observed. This analysis provides useful insights for sustainable design in flood-prone and ecologically sensitive areas, emphasizing the importance of protecting environmental systems and resource availability for future generations.

5. ACKNOWLEDGEMENTS

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