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Utilizing Time Series and Regression Analysis for Predicting Annual Surface Temperature Changes in the Philippines: An Empirical Approach

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ABSTRACT

Understanding changes in surface temperature in the Philippines plays an important role as it helps improve strategic planning for climate change impacts, influences decision-making in sectors such as agriculture and fisheries, and supports proactive disaster risk reduction and management. This study aims to delve deeper into the relationships between population growth rate, population density, forest cover loss, and changes in surface temperature in the Philippines, and seeks to create various models to predict future annual changes in surface temperature based on data from 2001 to 2023 using linear regression and time series analysis. The data were gathered from the websites of IMF Climate Change Dashboard, Global Forest Watch, and UN Department of Economic and Social Affairs. The study revealed that only population growth rate and population density are linearly related with annual changes in surface temperature, when combined, indicating significant predictors of surface temperature. Findings also revealed the increasing but fluctuating trend of surface temperature from 2001 to 2023. Moving average with interval of 2, as best-fit model, predicts a change of 1.4565 degree Celsius in surface temperature in the Philippines for the year 2024. With these, understanding changes in surface temperature based on several factors provides opportunity for the policymakers and future researchers pursuing to address and mitigate changes in the climate system in the Philippines.

Keywords: Surface Temperature, Climate Change, Time Series, Population, Philippines, Prediction

Introduction

Climate change and global warming have been considered as the most alarming and concerning environmental and meteorological issues in this time, and these two have several significant implications for the country of Philippines. As an archipelagic country located in the Pacific Ocean, it is particularly for this nation to be considered as one of the most vulnerable countries due to its geographical location and socio-economic conditions. These phenomena are causing by increasing emissions of greenhouse gasses in the Earth's atmosphere which is primarily due to human activities such as burning fossil fuels for energy generation, deforestation, industrial processes and urbanization (IPCC, 2023). These activities are continuously worsening the significant consequences of climate change and global warming in the world, particularly in the Philippines. In addition, the effects of climate change and global warming in the Philippines are manifold and severe as rising temperatures across the country have been observed and experienced by the people which lead to some heatwaves and increased heat stress cases, affecting human health and agricultural productivity.

Furthermore, changes in surface temperature have been traced due to several factors. One of these factors is urbanization. The idea of urbanization has been connected to population growth rate and density, and is significantly affecting the land and air surface temperature in the Philippines. A scientific study claimed that there is a significant difference in the surface air temperature (SAT) trends between urban and rural areas from 1951 to 2018 in the Philippines (Manalo, et.al., 2021). This implies the effects of urbanization, largely driven by increasing population in an area, on the country's temperature. In the study of Oliveros, Vallar, and Galvez (2019), they found that, in Metro Manila using Weather Research and Forecasting (WRF), the sensible heat flux of this urban and populated area is approximately $1.5 \times 10^8\ Jm^{-2}$, which is higher than the other areas. With this, they have concluded that there is an occurrence of urban heat island (UHI) effect in Metro Manila. The concept of urban heat island (UHI) effect refers to the occurrences of a phenomenon where cities or urban areas tend to ouster more heat than the nearby rural areas (Raza, et.al., 2021). As urbanization tends to relate population, this is also connected to the idea of land conversion wherein some farmlands or forests are being converted into industrial, commercial or for urbanization purposes. According to the study conducted in Guangdong-Hong Kong Greater Bay Area in China, there is evidence that rapid urbanization in an area can induce extensive loss of forest cover which reveals that 14.86% of the total urban area was obtained through forest cover loss from 1987 to 2017. In the case of Philippines, the trend of forest cover loss was projected from 2001 to 2020 wherein regions in the Philippines such as the provinces of Agusan del Sur, Palawan, and Zamboanga del Norte were found to be massively contributes to the occurrence of tree loss (Bobis, Dela Cerna, Malingan, and Yapan, 2023). Also, according to the study conducted by Global Forest Watch, it was reported that the Philippines have been losing around 1.29

million hectares of the forest cover from 2002 to 2020. And from 2001 to 2020, it was also reported that due to continuous tree loss, the annual average greenhouse gasses emitted into the atmosphere is around 37.6 megatons. Another study conducted by Almadrones-Reyes and Dagamac (2022) showed that there is evidence of increasing mean temperature in Metropolitan Manila from 2001 to 2019 which is equal to an increase of 4.02 degree Celsius and this was due to the declination of forest cover in the area. Several studies agreed that rising temperatures in some areas, especially in urban areas, are correlated with the loss of vegetation and increasing population within the area.

However, there are still gaps within these available studies towards changes in surface temperature, increasing population and forest cover loss. One of these is that many studies are mainly focused on a specific point in time or a short time span wherein there is still a need for a longer period of time to be analyzed in order to determine the full extent of changes and trends in surface temperature, population and forest cover. Another is the relationships between population growth rate, population density, forest cover loss and surface temperature are still complex and not fully understood, especially the case in the Philippines. Also, there is still a need for further studies that can make future projections of changes and relationships among the variables which are based on different scenarios in the Philippines wherein several studies are too focused in the case of Metro Manila and its nearby areas.

With these reasons, this study aimed to further explore the relationships among population growth rate, population density, forest cover loss, and changes in surface temperature in the Philippines, as well as to generate different models to predict the succeeding annual changes in surface temperature in the Philippines based on the data from year 2001 to 2023. This study can be valuable to environmental policymakers to develop and implement more targeted policies for the environment in order to reduce greenhouse gasses emission of the country, as well as to mitigate the continuous rising of temperatures and its impacts to the people of the Philippines. Specifically, this study aimed to:

1) Determine the trend of the surface temperature change in the Philippines from the year 2001 to 2023.
2) Find whether the annual change in surface temperature has a significant linear relationship with the following variables: (a) Annual Tree or Forest Loss, (b) Population Density, and (c) Population Growth Rate in the Philippines.
3) Construct a time series model to predict the annual change in surface temperature in the Philippines for the year 2024 using the following models:
    a. Linear
    b. Exponential
    c. Logarithmic
    d. Quadratic
    e. Polynomials (Cubic, Quartic, Quintic, and Sextic)
    f. Power
    g. Moving Average
    h. Exponential Smoothing
    i. Autoregression (1^{st}, 2^{nd}, 3^{rd}, 4^{th})
4) Determine the best fit model and predict the annual change in surface temperature in the Philippines in the year 2024.

Methods

In this study, the researcher conducted an empirical approach and employed an exploratory-predictive analysis to determine the relationships among the data, as well as to provide predictions based on the trend of the gathered data. The data used in this study were downloaded from the following websites: (a) IMF Climate Change Dashboard (https://climatedata.imf.org/pages/country-data); (b) Global Forest Watch (https://www.globalforestwatch.org/dashboards/country/PHL/?category=forest-change), and (c) UN Department of Economic and Social Affairs (https://population.un.org/wpp/).

Afterwards, the data were organized and run for analyses through Microsoft Excel. In data analysis, a scatter plot diagram was used to explore the trend of the annual change in surface temperature in the Philippines from 2001 to 2023. Simple linear regression was also used to identify the significant linear relationship between the independent and dependent variables. Meanwhile, multiple regression analysis was used to determine which independent variables can be utilized as significant factors to predict the next surface temperature in the country. The time series models were constructed using the coded data, as shown in Table 1. Lastly, observation of the differences between R-squared and standard error was being utilized to determine the best fit model in forecasting annual surface temperature in the Philippines.

Table 1. Coded Data for Time Series Analysis

Year	Code (Year)	Annual Surface Temperature
2001	1	0.825
2002	2	0.733
2003	3	0.795
2004	4	0.687
2005	5	0.782
2006	6	0.831
2007	7	0.875
2008	8	0.574
2009	9	0.718
2010	10	1.065
2011	11	0.62
2012	12	0.912
2013	13	1.057
2014	14	0.96
2015	15	1.155
2016	16	1.603
2017	17	1.3
2018	18	1.329
2019	19	1.407
2020	20	1.56
2021	21	1.431
2022	22	1.405
2023	23	1.508

Results

Objective 1. Trend of the Surface Temperature Change in the Philippines from 2001 to 2023

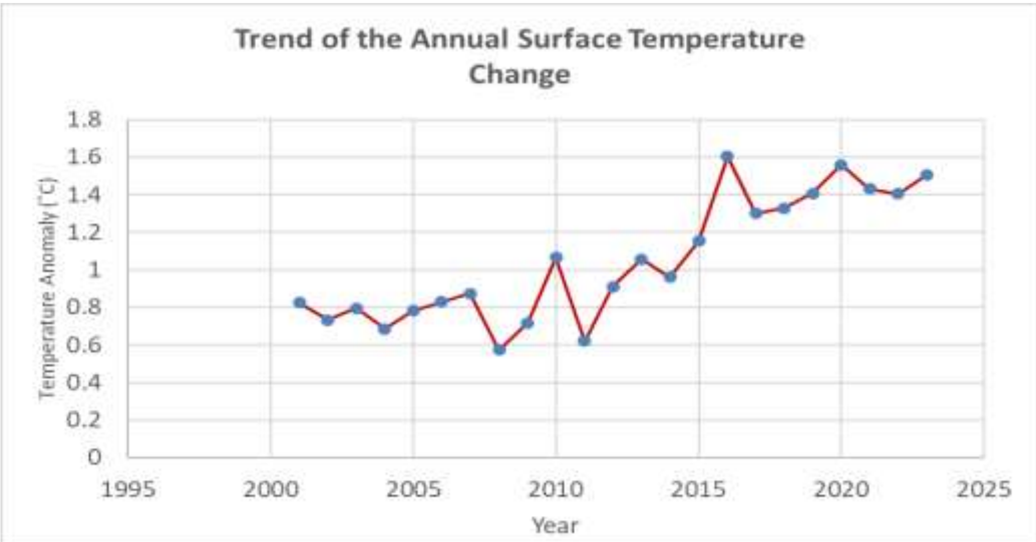

Figure 1. The trend of the annual surface temperature change in the Philippines from 2001 to 2023

As gleaned from Figure 1, the annual surface temperature in the Philippines gradually increases from 2001 to 2023. The trend suggests that surface temperature for the following years might possibly increase or decrease. In addition, from the year 2011 to 2016, there is a rapid increase of temperature in the country, and it is the highest surface temperature change recorded from 2001 to 2023. But generally, it follows an increasing pattern of changes in the annual surface temperature from the year 2001 to 2023.

With this result, the occurrences of increasing surface temperature across the globe can be traced back on several influences which are mainly related to human activities and factors. Many scientific researches have been published and have been mutually agreed that humans are causing the climate system to change and greatly influencing the temperature to continuously increase in some regions (IPCC, 2023). With the same report, human-driven changes such as conversions of farm or forest lands into commercial lands, urbanization which led to continuous loss of forest, and excessive accumulation of natural resources are some roots that alter the climate system in the Philippines. According to the AR6 Synthesis Report of IPCC (2023), it is very evident that human activities, primarily greenhouse gasses emissions, have caused global warming which results in reaching the 1.1-degree Celsius global surface temperature from the year 2011 to 2020. However, fluctuations of the trend particularly on the decreasing points along the recorded years might imply the trivial implications of the climate change mitigation and adaptation policies implemented by the national government with different sectors (Liza, 2017). As such, the primary root of these changes in the climate system, especially the surface temperature, is human and the solutions with these are also within the human domain.

Objective 2. Linear Relationships of Annual Change in Surface Temperature

2.1. Annual Change in Surface Temperature and Annual Tree Cover Loss

Table 2 presents the result of simple linear regression analysis between annual surface temperature and annual tree cover loss in the Philippines. As gleaned from the table, the annual tree cover loss has a significant linear relationship with the annual change in surface temperature ($p < 0.05$). Moreover, the annual tree cover loss, as variable, can be considered as significant predictor of the annual change in surface temperature in the Philippines using the equation $y = 0.0065x + 0.6401$ where x is the annual tree cover loss in kilo hectares, and y is the annual change in surface temperature in degrees Celsius. Using this equation, the annual tree cover loss, as variable, can explain around 27.42% of the variances in the annual change in surface temperature. With this, there is an increase of surface temperature by 0.6466 in degree Celsius for every one kilo hectare loss in tree or forest cover in the Philippines.

Table 2. Linear Regression Result of the Annual Surface Temperature and Annual Tree Cover

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.6401	0.1570	4.0764	0.0005
Annual Tree Cover Loss	0.0065	0.0023	2.8167	0.0103

$R^2 = 0.2742, p < 0.05$

2.2. Annual Change in Surface Temperature and Population Density

Table 3 presents the result of the simple linear regression analysis between the annual surface temperature and population density in the Philippines. Based on the table, the population density, as variable, has a linear relationship with the annual change in surface temperature ($p < 0.05$). The linear relationship between the annual change in surface temperature and population density does exist as a result of regression analysis, and population density can be considered as a significant predictor of the annual change in surface temperature. The equation that reflects the relationship of the two variables is $y = 0.0073x - 1.3387$ where x is the population density expressed in number of people per square kilometer, and y is the annual change in surface temperature. With this equation, around 74.27% of the variances in the annual change in surface temperature can be explained by the population density. As such, there is an added rate of 0.8513 for every 100 people per square kilometer as the population density in the Philippines.

Table 3. Linear Regression Result of the Annual Surface Temperature and Population Density

	Coefficients	Standard Error	t Stat	P-value
Intercept	-1.3387	0.3087	-4.3360	0.0003
Population Density	0.0073	0.0009	7.7862	0.0000

$R^2 = 0.7427, p < 0.05$

2.3. Annual Change in Surface Temperature and Population Growth Rate

Table 4 shows the result of simple linear regression of the annual change in surface temperature and population growth rate. As gleaned from the table, there exists a linear relationship between the annual change in surface temperature and the population growth rate in the Philippines ($p < 0.05$). The equation to be used in predicting annual change in surface temperature in terms of population growth rate is $y = -1.3246x + 3.4254$ where x is the population growth rate in percentage and y is the annual change in surface temperature. With this equation, there is a change in surface temperature of

2.1008 for every 1 percent growth rate of the population in the Philippines. The population growth rate is more likely as a significant predictor of the annual change in surface temperature according to Table 4. In addition, around 52.80% of the variances in the annual change in surface temperature can be explained by the population growth rate.

Table 4. Linear Regression Result of the Annual Surface Temperature and Population Growth

	Coefficients	Standard Error	t Stat	P-value
Intercept	3.4254	0.4926	6.9536	0.0000
Population Growth Rate	-1.3246	0.2733	-4.8469	0.0001

$R^2 = 0.5280, p < 0.05$

2. 4. Annual Change in Surface Temperature and the Three Variables

Table 5 shows the result of multiple linear regression analysis between the annual change in surface temperature and all the three variables: annual tree cover loss, population density, and population growth rate. As seen on the table, there exists a linear relationship between the annual change in surface temperature and the three variables ($p < 0.05$). The equation for this analysis which can be used to predict the change in the surface temperature in terms of the three variables is $y = 0.0021x_1 + 1.4724x_2 + 0.0132x_3 - 6.0342$ where y is the annual change in surface temperature in degree Celsius, $x_1$is the annual tree cover loss in kilo hectares, $x_2$is the population growth rate in percentage, and x_3 is the population density in terms of people per square kilometer. With this, there is a change of -3.2397 in the surface temperature for every 1 kilo hectares loss in forest cover, for every 1 percent of population growth rate, and for every 100 people per square kilometer as population density. In this analysis, only population growth rate and density can be considered as significant predictors of the annual change in surface temperature. Moreover, around 84.34% of the variances in the change in surface temperature can be explained by the three variables.

Table 5. Linear Regression Result of the Annual Surface Temperature and the Three Variables

	Coefficients	Standard Error	t Stat	P-value
Intercept	-6.0342	1.6869	-3.5772	0.0020
Annual Tree Cover Loss	0.0021	0.0012	1.7312	0.0996
Population Growth Rate	1.4724	0.5147	2.8605	0.0100
Population Density	0.0132	0.0024	5.3794	0.0000

$R^2 = 0.8434, p < 0.05$

These results are supported by Population Connection (2023) wherein it was claimed that population density and growth rate significantly contribute to climate change, particularly changes in surface temperature. With a rapid growth in population, humans tend to strain more resources, increase energy consumption, and increase demands of using transportation which causes more emissions of climate-changing gasses into the atmosphere. Also, in the study of Zhang, et.al. (2020), there is a projected increase of 2.2 degree Celsius in the population-weighted average temperature by the year of 2050 and this was due to the continuous increase in population.

Now, as the population rapidly increases, there is a high probability of increased loss of vegetation, particularly forest covers in the Philippines. This was affirmed by Meyerson (2004) such that deforestation tends to happen to the populated locations near forest areas as people clear the lands for farming or commercial purposes. However, in the same article, there is less clear relationship between the population growth and forest cover loss in the cases of Amazonia of South America and Central Africa. Also, those developed countries such as Russia and China have seen fast forest recovery even after an earlier deforestation. But these cases were due to rapid development and mitigation of the mentioned countries or areas.

Between forest cover loss and surface temperature, this relationship was explained by Tanjina Hasnat (2021) in his study wherein Dudpukuria-Dhopachari Wildlife Sanctuary in Bangladesh (similar ecological contexts with Philippines) have increased forest change and loss over decades, and been observed changes in land surface temperature from 2.3 degree Celsius to 3.0 degree Celsius. However, this relationship was not apparent and also found out that forest cover change and loss is not the main and only reason for the increased surface temperature in the area, rather the continuous global warming seems to be the major influence on the rising of temperature. Moreover, there is an asymmetric relationship between the tree cover loss and changes in surface temperature, and this relationship might vary depending on the local conditions of the area (Su, et.al, 2023). With this, there are still studies that may suggest an unclear relationship between tree cover loss and surface temperature which should be viewed in a broader context. Influence of tree cover loss may depend on several factors such as local climate conditions and land use patterns in the Philippines. Thus, based on the findings and supported studies, this suggests that annual tree cover loss might not be a good predictor of the changes in surface temperature in the Philippines.

Objective 3. Times Series Models of the Annual Surface Temperature in the Philippines

The following time series models have been used to determine how surface temperature changes over time in the Philippines.

a) Linear Time Series

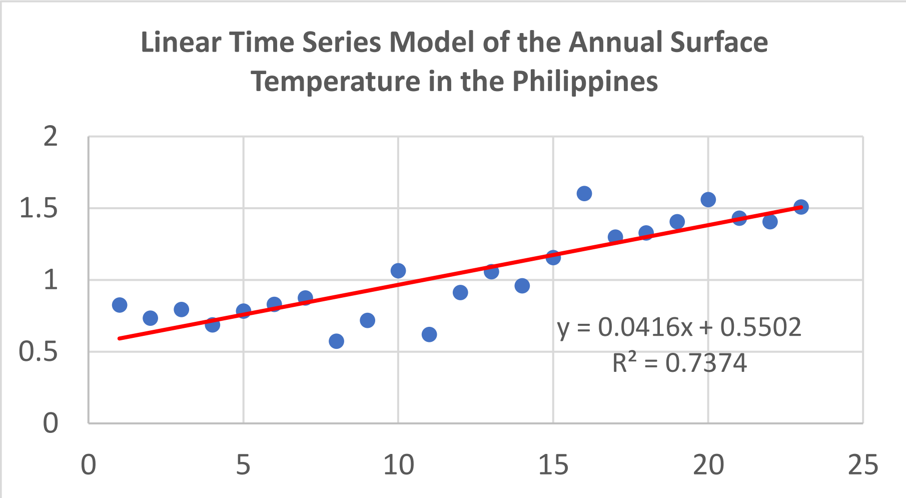

Figure 2. Linear Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 2 presents the linear time series model of the annual surface temperature in the Philippines from 2001 to 2023. This indicated that the model to be used to predicts the succeeding surface temperature in the Philippines is $y = 0.0416x + 0.5502$, where x is the number of years from the starting year. This model has a coefficient of determination of 0.7374 which indicates that 73.74% of the variances in the annual surface temperature can be explained by this generated linear time series model.

b) Exponential Times Series

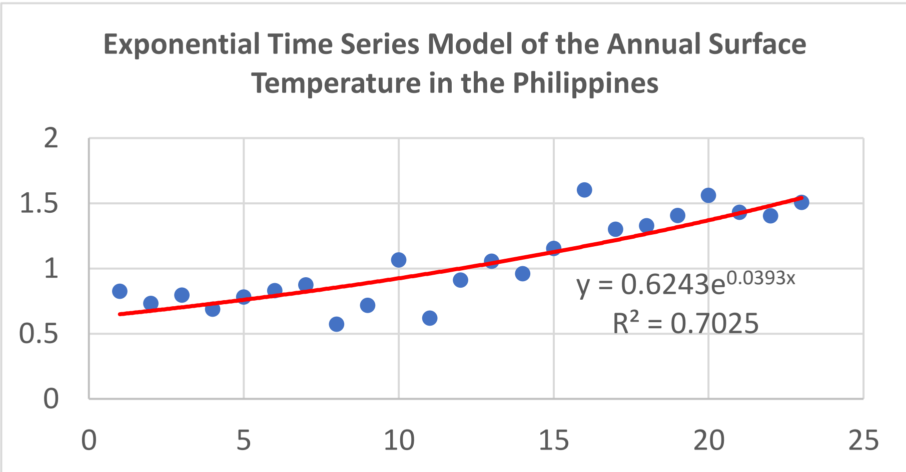

Figure 3. Exponential Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 3 shows the exponential time series model of the annual surface temperature in the Philippines from 2001 to 2023. This trend indicated that the model in predicting the next surface temperature in the Philippines is $y = 0.6243e^{0.0393x}$ with 0.7647 as coefficient of determination. This follows that this model can explain around 76.47% of the variances in the annual surface temperature.

c) Logarithmic Time Series

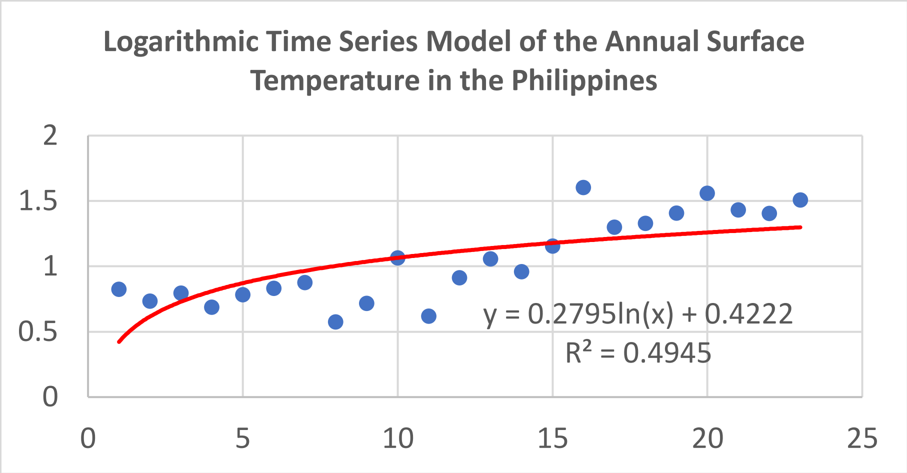

Figure 4. Logarithmic Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 4 presents the logarithmic time series model of the annual surface temperature in the Philippines from 2001 to 2023. The logarithmic model in predicting the succeeding surface temperature is $y = 0.2795\ln(x) + 0.4222$ with 0.4945 as coefficient of determination. This indicates that the model can explain about 49.45% of the variances in the annual surface temperature.

d) Quadratic Time Series

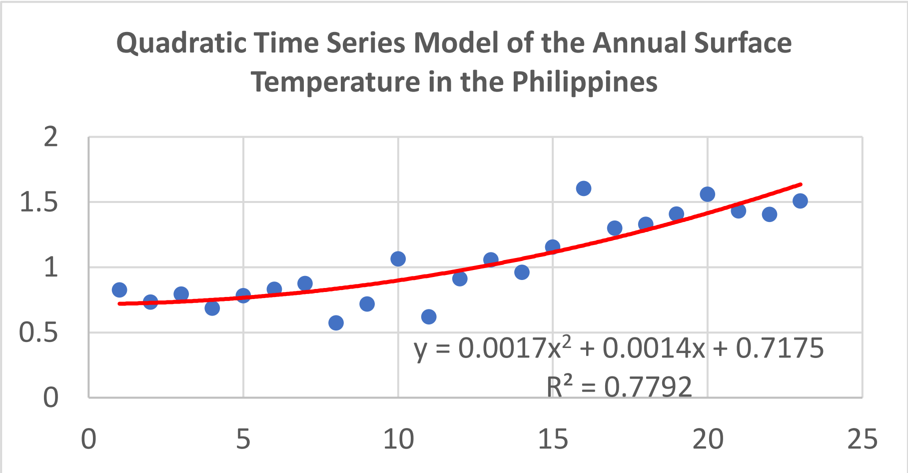

Figure 5. Quadratic Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 5 shows the quadratic time series model of the annual surface temperature in the Philippines from 2001 to 2023. The figure indicated that the quadratic model in predicting the next surface temperature in the Philippines is $y = 0.0017x^2 + 0.0014x + 0.7175$, where x is the number of years from the starting year. This model has a coefficient of determination of 0.7792 which indicates that around 77.92% of the variances in annual surface temperature can be explained by this model.

e) Polynomials (Cubic, Quartic, Quintic, Sextic)

e.1. Cubic Time Series

Figure 6 presents the cubic linear time series model of the annual surface temperature in the Philippines from 2001 to 2023. This figure indicated that the time series model in predicting the surface temperature is $y = -0.0003x^3 + 0.0132x^2 - 0.1120x + 0.9682$ which has a coefficient of determination of 0.8307. This simply implies that this model can explain around 83.07% of the variances in the annual surface temperature in the Philippines.

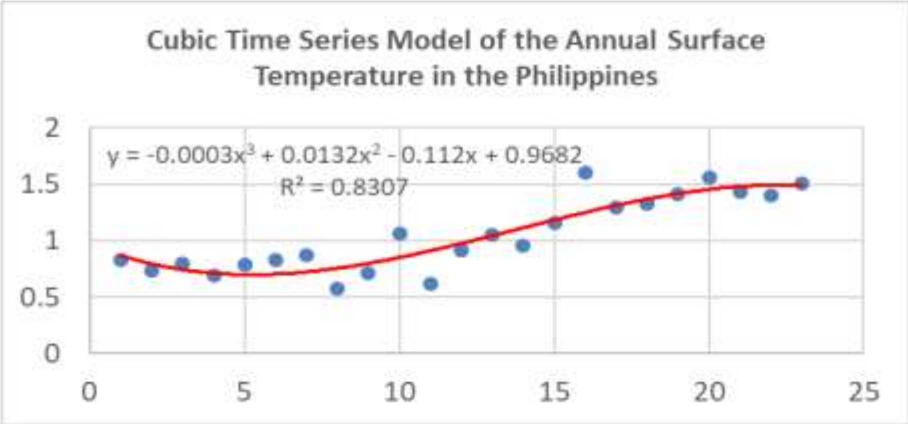

Figure 6. Cubic Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

e.2. Quartic Time Series

Figure 7 shows the quartic time series model of the annual surface temperature in the Philippines from 2001 to 2023. The quartic model in predicting the surface temperature in the Philippines is $y = -0.00003x^4 + 0.0010x^3 - 0.0071x^2 + 0.0018x + 0.8056$ with a coefficient of determination of 0.8426. This model indicates that it can explain about 84.26% of the variances in the annual surface temperature in the Philippines.

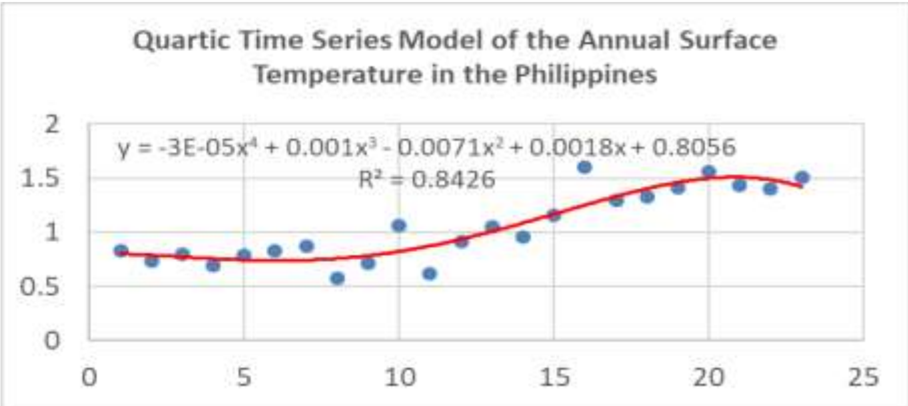

Figure 7. Quartic Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

e.3. Quintic Time Series

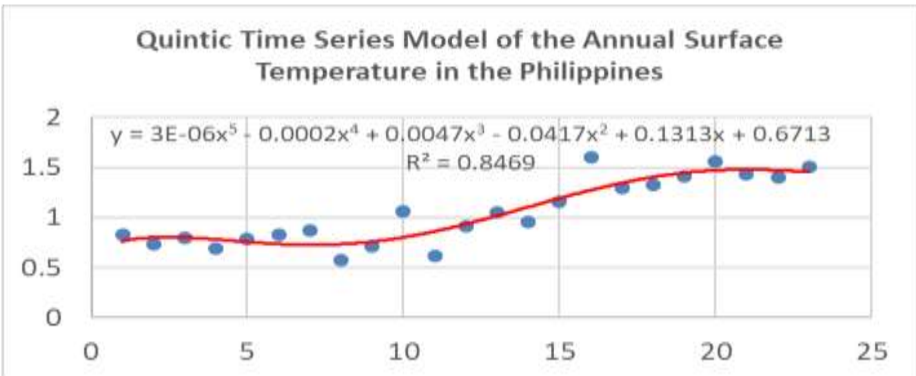

Figure 8. Quintic Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 8 presents the quintic time series model of the annual surface temperature in the Philippines from 2001 to 2023. The quintic model that can be used to predict surface temperature is $y = 0.000003x^5 - 0.0002x^4 + 0.0047x^3 - 0.0417x^2 + 0.1313x + 0.6713$ with a coefficient of determination of 0.8469. This indicates that around 84.69% of the variances in the annual surface temperature in the Philippines can be explained by the quintic model.

e.4. Sextic Time Series

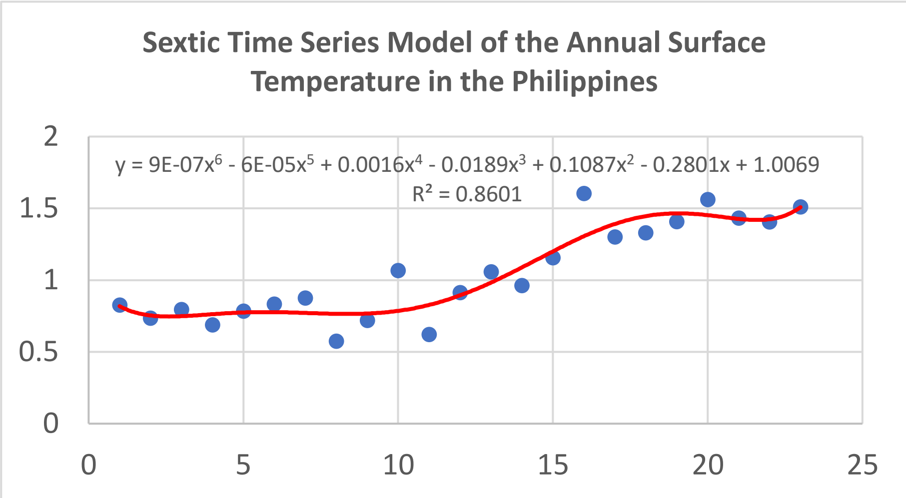

Figure 9. Sextic Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 9 shows the sextic time series model of the annual surface temperature in the Philippines from 2001 to 2023. The figure indicated that the sextic model in predicting surface temperature is $y = 0.0000009x^6 - 0.00006x^5 + 0.0016x^4 - 0.0189x^3 + 0.1087x^2 - 0.2801x + 1.0069$ with a coefficient of determination of 0.8601. This implies that this model can explain about 86.01% of the variances in the annual surface temperature in the Philippines.

f) Power Time Series

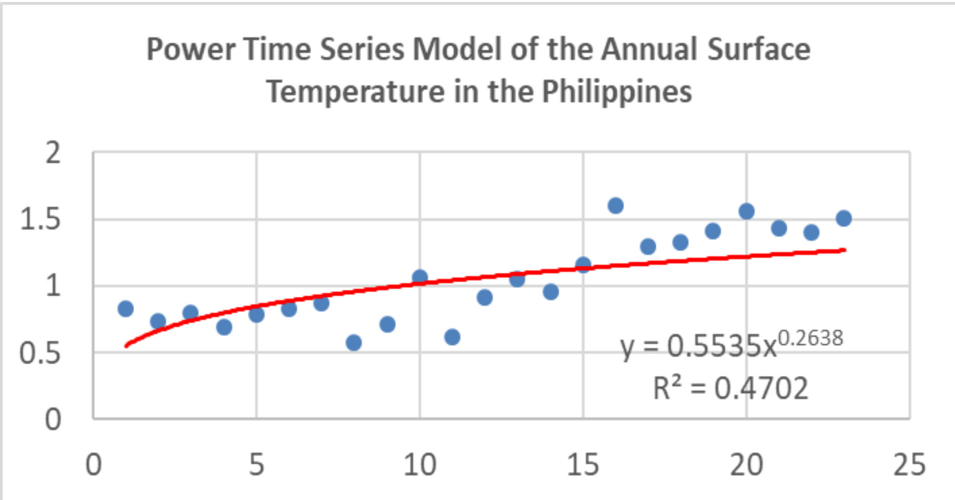

Figure 10. Power Trend of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 10 presents the power time series model of the annual surface temperature in the Philippines from 2001 to 2023. This figure indicated that the model for power time series in predicting the annual surface temperature is $y = 0.5535x^{0.2638}$ with 0.5808 as coefficient of determination. This model can explain around 58.08% of the variances in the annual surface temperature.

g) Moving Average

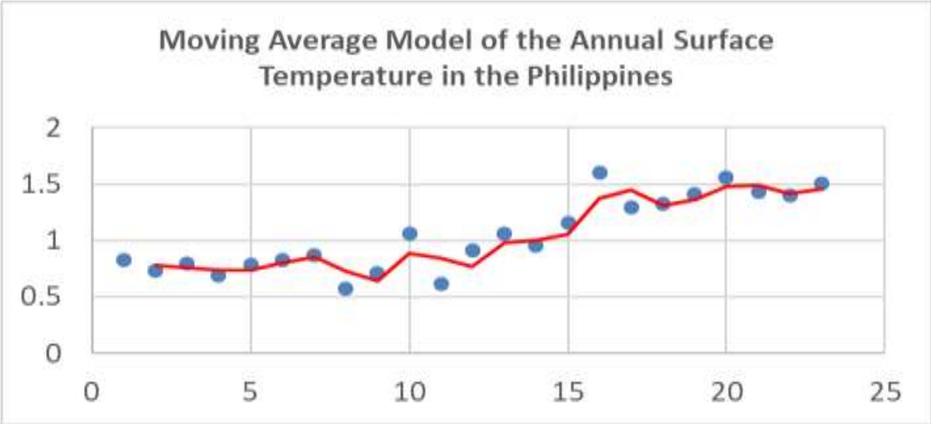

Figure 11. Moving Average Model of the Annual Surface Temperature in the Philippines from 2001 to 2023

Figure 11 presents the moving average model of the actual data of surface temperature in the Philippines and its forecast from the year 2001 to 2023 with an interval of 2. The moving average model in forecasting the surface temperature is $y = \frac{Y_t + Y_{t+1}}{2}$, where t is the time period and Y is the actual data of surface temperature.

h) Exponential Smoothing

Figure 12 shows the exponential smoothing model for the annual surface temperature in the Philippines from 2001 to 2023 at a damping factor of 0.20. The model for the exponential smoothing is $y_{t+1} = 0.8Y_t + 0.2y_t$ where y_{t+1} is the forecasted value, Y_t is the actual data, and y_t is the expected value of surface temperature.

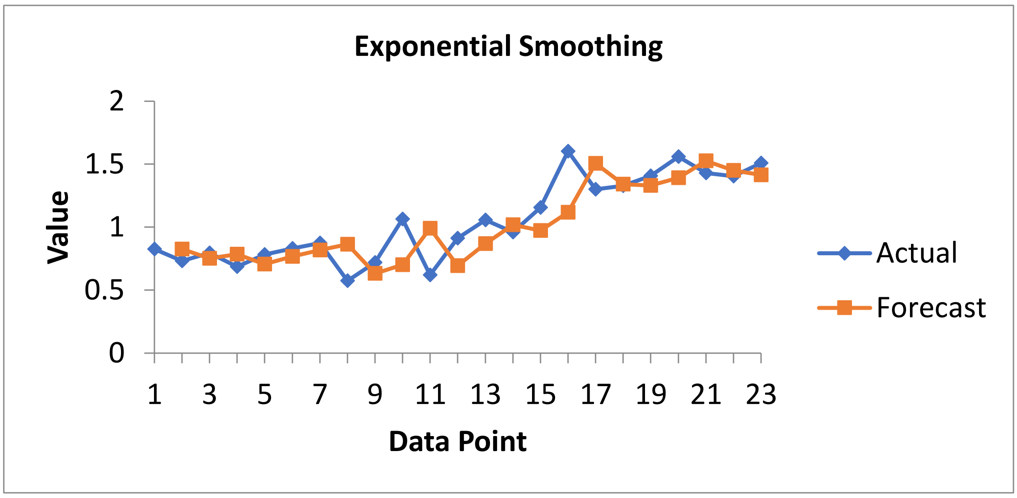

Figure 12. Exponential Smoothing Time Series Model of the Annual Surface Temperature in the Philippines from 2001 to 2023

i) Auto

i.1. First Autoregression

Table 6 presents the result of the first autoregression of the annual surface temperature in the Philippines from 2001 to 2023. The first autoregression model that can be used to predict the succeeding surface temperature in the Philippines is $y = 0.2180 + 0.8182y_{n-1}$ with 0.6211 as coefficient of determination. This means that this model can explain 62.11% of the variances in the annual surface temperature.

Table 6. First Autoregression Result of the Annual Surface Temperature

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.2180	0.1536	1.4194	0.1712
X Variable 1	0.8182	0.1429	5.7259	0.0000

$R^2 = 0.6211, p < 0.05, p < 0.01$

i.2. Second Autoregression

Table 7 presents the result of the second autoregression of the annual surface temperature in the Philippines from 2001 to 2023. The table indicated that the model for second autoregression to be used in predicting next surface temperature is $y = 0.1639 + 0.5466y_{n-1} + 0.3401y_{n-2}$. This model has a 0.6570 as coefficient of determination which implies that around 65.70% of the variances in the annual surface temperature can be explained by the model.

Table 7. Second Autoregression Result of the Annual Surface Temperature

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.1639	0.1620	1.0117	0.3251
X Variable 1	0.5466	0.2216	2.4663	0.0239
X Variable 2	0.3401	0.2274	1.4959	0.1520

$R^2 = 0.6570, p < 0.05, p < 0.01$

i.3. Third Autoregression

Table 8 presents the result of the third autoregression of the annual surface temperature in the Philippines from 2001 to 2023. The third autoregression model in predicting next surface temperature is $y = 0.0796 + 0.3678y_{n-1} + 0.0760y_{n-2} + 0.5503y_{n-3}$ with 0.7465 as coefficient of determination. The generated model can explain around 74.65% of the variances in the annual surface temperature.

Table 8. Third Autoregression Result of the Annual Surface Temperature

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.0796	0.1539	0.5173	0.6120
X Variable 1	0.3678	0.2122	1.7333	0.1023
X Variable 2	0.0760	0.2294	0.3312	0.7448
X Variable 3	0.5503	0.2174	2.5313	0.0222

$R^2 = 0.7465, p < 0.05, p < 0.01$

i.4. Fourth Autoregression

Table 9 presents the result of the fourth autoregression of the annual surface temperature in the Philippines from 2001 to 2023. The table indicated that the model for fourth autoregression is $y = 0.1191 + 0.3421y_{n-1} + 0.0431y_{n-2} + 0.5604y_{n-3} + 0.0231y_{n-4}$ with 0.7461 coefficient of determination. This implies that this model can explain about 74.61% of the variances in the annual surface temperature.

Table 9. Fourth Autoregression Result of the Annual Surface Temperature

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.1191	0.1668	0.7142	0.4869
X Variable 1	0.3421	0.2575	1.3282	0.2053
X Variable 2	0.0431	0.2374	0.1817	0.8584
X Variable 3	0.5604	0.2362	2.3722	0.0326
X Variable 4	0.0231	0.2796	0.0825	0.9354

$R^2 = 0.7461, p < 0.05, p < 0.01$

Summary Table

Table 10 shows the overview of the time series models of the annual surface temperature in the Philippines from 2001 to 2023. This table also illustrates that sextic time series model has the highest R-squared value which is 86.01%, while the lowest R-squared among the models is the logarithmic times series with 49.45%.

Table 10. Time Series Models and R-Squared

Model	Equation	R Squared
Linear	$y = 0.0416x + 0.5502$	73.74%
Exponential	$y = 0.6243e^{0.0393x}$	76.47%
Logarithmic	$y = 0.2795\ln(x) + 0.4222$	49.45%
Quadratic	$y = 0.0017x^2 + 0.0014x + 0.7175$	77.92%
Cubic	$y = -0.0003x^3 + 0.0132x^2 - 0.112x + 0.9682$	83.07%
Quartic	$y = -0.00003x^4 + 0.001x^3 - 0.0071x^2 + 0.0018x + 0.8056$	84.26%
Quintic	$y = 0.000003x^5 - 0.0002x^4 + 0.0047x^3 - 0.0417x^2 + 0.1313x + 0.6713$	84.69%
Sextic	$y = 0.0000009x^6 - 0.00006x^5 + 0.0016x^4 - 0.0189x^3 + 0.1087x^2 - 0.2801x + 1.0069$	86.01%
Power	$y = 0.5535x^{0.2638}$	58.08%
Moving Average	$y = \frac{Y_t + Y_{t+1}}{2}$	N/A
Exponential Smoothing	$y_{t+1} = 0.8Y_t + 0.2y_t$	N/A
Autoregression		
1. First Autoregression	$y = 0.2180 + 0.8182y_{n-1}$	62.11%
2. Second Autoregression	$y = 0.1639 + 0.5466y_{n-1} + 0.3401y_{n-2}$	65.70%
3. Third Autoregression	$y = 0.0796 + 0.3678y_{n-1} + 0.0760y_{n-2} + 0.5503y_{n-3}$	74.65%
4. Fourth Autoregression	$y = 0.1191 + 0.3421y_{n-1} + 0.0431y_{n-2} + 0.5604y_{n-3} + 0.0231y_{n-4}$	74.61%

Objective 4. Best Fit Model and Prediction of the Annual Change in Surface Temperature in the Philippines

Table 11 presents the summary of the possible models to be used in predicting the change in surface temperature in the Philippines for the year 2024. This table shows the statistical accuracy of the models which is being considered as a choosing factor to be the best fit model in this study.

Table 11. Best Fit Model and Prediction of the Annual Surface Temperature for the year 2024

Model	Equation	R Squared	Standard Error	Difference	Prediction for the year 2024
Linear	$y = 0.0416x + 0.5502$	73.74%	0.1723	73.57%	1.5486
Exponential	$y = 0.6243e^{0.0393x}$	76.47%	0.1643	76.31%	1.6033
Logarithmic	$y = 0.2795\ln(x) + 0.4222$	49.45%	0.2390	49.21%	1.3105
Quadratic	$y = 0.0017x^2 + 0.0014x + 0.7175$	77.92%	0.1581	77.76%	1.7303
Cubic	$y = -0.0003x^3 + 0.0132x^2 - 0.112x + 0.9682$	83.07%	0.1707	82.90%	1.7362
Quartic	$y = -0.00003x^4 + 0.001x^3 - 0.0071x^2 + 0.0018x + 0.8056$	84.26%	0.2435	84.02%	0.6299
Quintic	$y = 0.000003x^5 - 0.0002x^4 + 0.0047x^3 - 0.0417x^2 + 0.1313x + 0.6713$	84.69%	0.2800	84.41%	2.3088
Sextic	$y = 0.0000009x^6 - 0.00006x^5 + 0.0016x^4 - 0.0189x^3 + 0.1087x^2 - 0.2801x + 1.0069$	86.01%	5.5143	80.50%	20.6989
Power	$y = 0.5535x^{0.2638}$	58.08%	0.2389	57.84%	1.2211
Moving Average	$y = \frac{Y_t + Y_{t+1}}{2}$	N/A	0.0376	N/A	1.4565
Exponential Smoothing	$y_{t+1} = 0.8Y_t + 0.2y_t$	N/A	0.1146	N/A	1.4892
Autoregression					
1. First Autoregression	$y = 0.2180 + 0.8182y_{n-1}$	62.11%	0.2097	61.90%	1.4518
2. Second Autoregression	$y = 0.1639 + 0.5466y_{n-1} + 0.3401y_{n-2}$	65.70%	0.1997	65.50%	1.4660
3. Third Autoregression	$y = 0.0796 + 0.3678y_{n-1} + 0.0760y_{n-2} + 0.5503y_{n-3}$	74.65%	0.1730	74.48%	1.5285
4. Fourth Autoregression	$y = 0.1191 + 0.3421y_{n-1} + 0.0431y_{n-2} + 0.5604y_{n-3} + 0.0231y_{n-4}$	74.61%	0.1709	74.44%	1.5335

As gleaned from the Table 11, the best-fit model in this study is the moving average model with interval of 2 as it is very evident on its lowest standard error of 0.0376, indicating that this model has a greater accuracy and reliability on predicting the succeeding annual change in surface temperature in the Philippines compared to the other generated models. Moreover, the cubic, quartic, quintic and sextic polynomial times series models showed relatively high R-squared values which indicates a good characteristic to be fit on the data. Also, the logarithmic function model exhibited the weakest accuracy and reliability to predict the annual change in surface temperature, having a R-squared value of 49.45%. This implies that the logarithmic function model has the weakest fit on the data. As such, the moving average model with interval of 2 demonstrated its superiority among the alternative models in predicting the succeeding annual change in surface temperature by filtering out the data noises and smoothing out some short-term fluctuations in the trend from year 2001 to 2023.

Discussion

With the ongoing effects of climate change, scientists should give consideration to several variables relevant to natural and socioeconomic factors that have been scientifically causing changes in the climate system in the Philippines. Provision of relevant information through climate models regarding the continuous rising temperature, specifically the future surface temperature to be experienced in the Philippines, will allow different sectors to create and implement more effective and efficient policies to mitigate the impacts and to take proactive measures to address these rapid changes in temperature. With these provisions, humans will empower themselves to make informed decisions concerning issues such as health care, agriculture, food security, and others.

After data analysis, the following are the summary of findings in this study:

a) The trend of the annual changes in surface temperature from 2001 to 2023 demonstrates an increasing pattern with some periods of fluctuations. From 2014 to 2016, it emphasizes the rapid increase of surface temperature in the Philippines while being addressed and taken into consideration by the environmental sectors and even national government. Moreover, the decreasing periods might indicate that several sectors effectively and efficiently mitigate the continuous rising of surface temperature and implemented concrete policies and measures to address the occurrences of surface temperature rising.

b) The annual tree or forest cover loss, population density and population growth rate in the Philippines all showed significant linear relationship with the annual change in surface temperature. But, in the multiple linear regression analysis, only population density and population growth rate had a linear relationship with the annual change in surface temperature which implies that the population density and population growth rate can be considered as significant predictors of the annual change in surface temperature in the Philippines.

c) The time series models of the annual changes in surface temperature in the Philippines from year 2001 to 2023 are:

Linear	$y = 0.0416x + 0.5502$
Exponential	$y = 0.6243e^{0.0393x}$
Logarithmic	$y = 0.2795 \ln(x) + 0.4222$
Quadratic	$y = 0.0017x^2 + 0.0014x + 0.7175$
Cubic	$y = -0.0003x^3 + 0.0132x^2 - 0.112x + 0.9682$
Quartic	$y = -0.00003x^4 + 0.001x^3 - 0.0071x^2 + 0.0018x + 0.8056$
Quintic	$y = 0.000003x^5 - 0.0002x^4 + 0.0047x^3 - 0.0417x^2 + 0.1313x + 0.6713$
Sextic	$y = 0.0000009x^6 - 0.00006x^5 + 0.0016x^4 - 0.0189x^3 + 0.1087x^2 - 0.2801x + 1.0069$
Power	$y = 0.5535x^{0.2638}$
Moving Average	$y = \frac{Y_t + Y_{t+1}}{2}$
Exponential Smoothing	$y_{t+1} = 0.8Y_t + 0.2y_t$
Autoregression	
1. First Autoregression	$y = 0.2180 + 0.8182y_{n-1}$
2. Second Autoregression	$y = 0.1639 + 0.5466y_{n-1} + 0.3401y_{n-2}$
3. Third Autoregression	$y = 0.0796 + 0.3678y_{n-1} + 0.0760y_{n-2} + 0.5503y_{n-3}$
4. Fourth Autoregression	$y = 0.1191 + 0.3421y_{n-1} + 0.0431y_{n-2} + 0.5604y_{n-3} + 0.0231y_{n-4}$

d) The best-fit model is the moving average model with an interval of 2. Using this model, the predicted change in surface temperature for the year 2024 is 1.4565 degree Celsius.

In this study, there are some problems encountered especially on the part of gathering data. Due to limited access to data, it is difficult to look out and gather consistent data to a specific region or country regarding surface temperature, population-related factors and forest cover loss in the Philippines. Also, this study was limited to basic linear regression approaches and time series analysis models, and no other predictive modeling being used. Based on the findings of this study, policymakers and other related sectors may consider the following recommendations. The national government and other related sectors should focus on implementing effective measures, like family planning and reproductive health services and controlling migration flows across the regions, in order to control the rapid growth in population. Policies toward ensuring a greener country despite rapid development of the country or 'urban greening' should be evaluated and reevaluated if there exists. Promoting sustainable living practices may prioritize the communities in order to progressively minimize the impacts of climate change and population growth.

Further studies may be conducted to ensure the accuracy and reliability of the model in this study. It may be conducted using other advanced mathematical models like autoregressive moving average (ARMA), random forest, and deep learning neural networks model. Also, future studies may focus on a specific type of surface temperature, whether into land surface temperature, air surface temperature, or sea surface temperature in the Philippines.

Conclusion

The findings of this study provide essential perspectives into the trends of annual changes in surface temperature and predictors in the Philippines from 2001 to 2023. While there has been an observed increase in surface temperature during this period based on historical data trends, fluctuations within the data suggest efforts by the government and concerned sectors to address the rapid and continuous rise in surface temperature. The study reveals that, when combined, population density and population growth rate demonstrate a significant linear relationship with annual changes in surface temperature in the Philippines. These variables can be considered as significant predictors of annual temperature changes. Interestingly, even though annual tree or forest cover loss does not exhibit a linear relationship with annual temperature changes when combined with population density and growth rate, it remains significant when analyzed using linear regression individually. This highlights the need for further investigation and understanding of these factors for accurate forecasting and addressing surface temperature changes in the Philippines.

Different models have been explored in the time series analysis to provide predictions of changes in surface temperature in the Philippines. The moving average model with interval of 2 has been considered the best-fit model in this study as it is the most accurate and reliable for predicting surface temperature among the models having the lowest standard error among the models. This suggests that this model can be used as a tool and guide for environmental policymakers as well as the national government to anticipate future changes in surface temperature in the country. With this, the study emphasized the essence of consistent monitoring of the surface temperature in order for the policymaker and national government to come up with targeted strategies and measures to address any continuous changes in surface temperature in the Philippines that causes risks and threats to the people of the Philippines.

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Appendix

Summary of Raw Data Gathered with Year Code

Year	Code (Year)	Annual Tree Loss (Kha)	Population Growth Rate (%)	Population Density (People per Km)	Annual Surface Temperature
2001	1	34.5	2.14	265.42	0.825
2002	2	31.9	2.08	270.95	0.733
2003	3	34.8	2.04	276.48	0.795
2004	4	48.2	2.01	282.03	0.687
2005	5	49.4	1.95	287.54	0.782
2006	6	57	1.9	293.01	0.831
2007	7	65.9	1.89	298.54	0.875
2008	8	38.4	1.89	304.17	0.574
2009	9	60.2	1.86	309.82	0.718
2010	10	102	1.82	315.46	1.065
2011	11	33	1.8	321.13	0.62
2012	12	58.9	1.76	326.77	0.912
2013	13	58.5	1.7	332.33	1.057
2014	14	102	1.63	337.75	0.96
2015	15	65.6	1.68	343.44	1.155
2016	16	128	1.79	349.58	1.603
2017	17	114	1.78	355.8	1.3
2018	18	70.3	1.71	361.9	1.329
2019	19	63.8	1.67	367.94	1.407
2020	20	63.4	1.64	373.97	1.56
2021	21	48.6	1.51	379.6	1.431
2022	22	84.1	1.47	385.2	1.405
2023	23	42.7	1.54	391.12	1.508