Zagazig J. Agric. Res., Vol. 50 No. (4) 2023 493-504

Soil Science and Agricultural Engineering

Available online at http://zjar.journals.ekb.eg

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

UTILIZING GIS TECHNOLOGY FOR MAPPING LOCAL CLIMATE ZONES: A CASE STUDY OF THE PHILIPPINES

Ibrahim A.I. Balata[1*], I.M. Abdel Hameed[2] and M.M. El-Feky[2]

1. Emerg. Dept., Mechanics and Electricity Dept., Minist. Water Res. and Irrigation, Egypt.
2. Nat. Res., Inst. Asian Studies and Res., Zagazig Univ., Egypt

Received: 07//08/2023 ; Accepted: 27/08/2023

ABSTRACT: The focus of this study is the Philippines, a Southeast Asia country with a land area of around 300,000 square kilometers, comprising 7,641 islands, its geographical location is between 4° 40' and 21° 10' North latitude and 116° 40' and 126° 34' East longitude in Southeast Asia. In this research, we aim to analyze the impact of climate change on surface water resources in the country. To achieve this objective, we will evaluate the distribution of the temperature and rainfall in different regions of the Philippines, investigate the current effects of climate change on surface water resources, and predict the future implications of climate change on surface water resources. Data related to monthly climate variables were gathered for the Philippines region from 57 meteorological stations, covering the period from 1991 to 2020. The variables included air temperature (minimum and maximum), wind speed, air humidity, sunshine period, irradiance, and precipitation. The sources of this data were the Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) for the Philippines, as well as the CLIMWAT databases. Graphs are created to visualize changes over time in weather stations. Data were presented using Boxplot. The aridity index was calculated to classify the different climates and assess the available water resources in the Philippines. For geographical areas with similar weather conditions. The aridity scale was calculated as a means of describing the water shortage in each area. The average annual of reference evapotranspiration of water (ETo) of the Philippines is (3.87 mm/day). The correlation between (ETo) and solar radiation is 0.9, which indicates that they are strongly positively correlated, and the correlation between (ETo) with sunshine period, maximum, mean, and minimum air temperature (0.72, 0.71, 0.63, 0.43) respectively indicating that they are positively correlated. The results concluded that the Philippines is divided into four climatic regions.

Key words: Climatic changes, Rainfall, Temperature, reference evapotranspiration, water resources, Philippines.

INTRODUCTION

Based on lates comprehensive emissions scenarios (Joint Social and Economic Pathways, SSPs), it is projected that the average global temperature will increase by approximately 1.0°C, over the 20th century. Furthermore, it is anticipated that by 2100,

This increase could range between 1.3 and 5.1°C **(Riahi *et al.*, 2017; Rogelj *et al.*, 2018).** human activities like burning fossil fuels cause an excessive increase in greenhouse gases, driving global warming. Rising temperatures have far-reaching consequences for the Earth climate affecting factor like water vapor, precipitation and groundwater recharge. Climate change has significant impacts on natural systems and human societies, with developing nations lacking capacity to adapt, thorough research on the diverse consequences of temperature changes in different regions is urgently needed, using the available climate

---

*** Corresponding author: Tel.** : +201128720066

E-mail address: ibrahimbalataa@gmail.com

models **(Teutschbein and Seibert, 2012; Turco *et al.*, 2017)**.

The Philippine is composed of 7641 islands and has land area of 300000 km^2. Its climate is influenced by large-scale atmospheric phenomena and experiences rains almost all year round, but with uneven distribution and extreme events such as floods and droughts, causing imbalances in its water resources **(Jose *et al.*, 1993)**.

Global warming is expected to occur due to increased carbon dioxide concentration in the atmosphere. Global surface temperature will increase by at least 2.0°C by the next century **(IPCC, 1996a)**. Due to Significant changes in the earth's climatic system, there is an expected alteration of rainfall and temperature in the Philippines, leading to extreme climatic events have adversely affected the country's economy. El Niño-related droughts affected not only the water sector but also other sectors such as agriculture, health, and environment the Philippine also experiences imbalances in its water resources due to uneven distribution and extreme events such as floods and droughts. **(Jose, 1992).** The El Niño-related drought of 1982–83, for example, has affected thousands of agricultural areas in the Philippines, including multipurpose reservoirs, where very low water levels were recorded.

Thus, the main goal of this research study was to evaluate the effects of climate change on surface water resources in the Philippines. This goal was accomplished by pursuing the following objective: (i) evaluating the temporal and spatial distribution of temperature and rainfall in the Philippines, (ii) assessing the impacts of some climate change on surface water resources in the Philippines. (iii) investigating the anticipated future effects of climate change on surface water resources in the Philippines.

MATERIALS AND METHODS

Study Area

This study primarily concentrates on the Philippines, a country in Southeast Asia that comprises 7,641 islands (as shown in Fig. 1). The land area of the Philippines is approximately 30,000 square kilometers. Geographically, the Philippines is positioned between 4° 40' and 21° 10' North latitude and 116° 40' and 126° 34' East longitude in Southeast Asia.

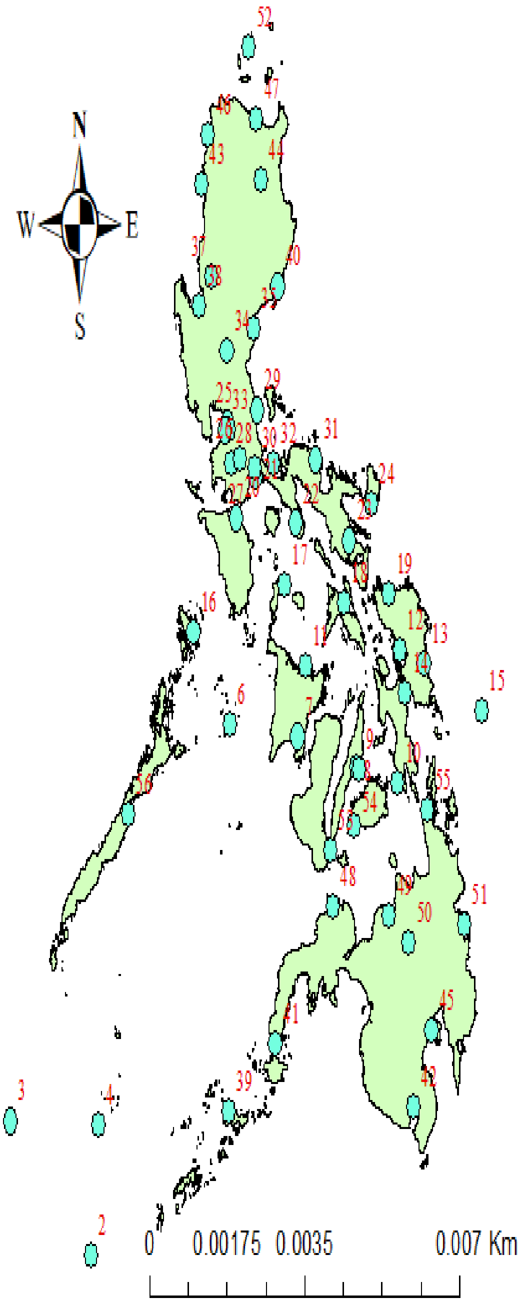
The average elevation of the Philippines is around 442 meters above sea level, with its highest point being Mount Apo at 2,954 meters and its lowest point being the Philippine Sea at 0 meters. For this study, data on monthly climate variables from 57 meteorological stations in the Philippines between 1991 and 2020 were collected. The variables included minimum and maximum air temperature (°C), air humidity (%), wind speed (km/day), sunshine period (hr), radiation (MJ/m^2/day), and rainfall (mm). The data were obtained from the Climatology and Agrometeorology Division of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), as well as the CLIMWAT 2.0 databases. The longitudes, latitudes, and altitudes of the meteorological stations are shown in Fig. 1.

Temporal Changes In Temperatures, and Precipitation

Graphs were created using Microsoft Excel 356 to visualize the changes over time in data from meteorological stations, specifically maximum and minimum temperatures, and precipitation. The XLSTST program version 2016 was used to present the annual averages of various climatic data obtained from meteorological stations in the Philippines, including maximum and minimum temperatures, precipitation, humidity, number of hours of sunshine, and wind speed. The data was displayed using Boxplot.

Aridity indices

Aridity indices are measures of the dryness of a region or climate. They are used to assess the availability of water resources and the potential for drought, as well as to classify different types of climates (**FAO, 1998; Thornthwaite, 1948**). Aridity indices take into account factors such as temperature, precipitation, and evaporation, and are typically expressed as a ratio of precipitation to potential evaporation (**Van der Schrier *et al.*, 2013; Vicente-Serrano *et al.*, 2010**).



No.	Station name	Latitude	Longitude
1	TARAKAN-JUWATA	3.33	117.56
2	TAWAU	4.26	117.88
3	KOTA-KINABALU	5.93	116.05
4	SANDAKAN	5.9	118.06
5	BASCO	20.45	121.96
6	CUYO	10.85	121.03
7	ILOILO	10.7	122.56
8	LAHUG	10.33	123.9
9	MACTAN	10.3	123.96
10	MAASIN	10.13	124.83
11	ROXAS	11.58	122.75
12	CATBALOGAN	11.78	124.88
13	BORONGAN	11.61	125.43
14	TACLOBAN	11.25	125
15	GUIUAN	11.03	126.73
16	CORON	12	120.2
17	ROMBLON	12.58	122.26
18	MASBATE	12.36	123.61
19	CATARMAN	12.48	124.63
20	CALAPAN	13.41	121.18
21	LUCENA	13.93	121.61
22	AURORA	13.35	122.51
23	LEGASPI	13.13	123.73
24	VIRAC	13.58	124.23
25	MANILA	14.58	120.98
26	LOS-BANOS	14.16	121.25
27	AMBULONG	14.08	121.05
28	NINOY-AQUINO-INTER-N	14.51	121
29	INFANTA	14.75	121.65
30	TAYABAS	14.03	121.58
31	DAET	14.13	122.98
32	ALABAT	14.08	122.01
33	SANGLEY-POINT	14.5	120.91
34	CABANATUAN	15.48	120.96
35	BALER	15.76	121.56
37	BAGUIO	16.41	120.6
38	DAGUPAN	16.05	120.33
39	JOLO	6.05	121
40	CASIGURAN	16.28	122.11
41	ZAMBOANGA	6.9	122.06
42	GEN_-SANTOS	6.11	125.18
43	VIGAN	17.56	120.38
44	TUGUEGARAO	17.61	121.73
45	DAVAO	7.06	125.6
46	LAOAG	18.18	120.53
47	APARRI	18.36	121.63
48	DIPOLOG	8.6	123.35
49	CAGAYAN-DE-ORO	8.48	124.63
50	MALAYBALAY	8.15	125.08
51	HINATUAN	8.36	126.33
52	CALAYAN	19.26	121.46
53	DUMAGUETE	9.3	123.3
54	TAGBILARAN	9.6	123.85
55	SURIGAO	9.8	125.5
56	PUERTO-PRINCESA	9.75	118.73
57	HENGCHUN	21.93	120.83

Fig. 1. Locations map of different weather stations (green dots) in the Philippines (map was created by researcher using ArcMap)

Aridity index (AI)

One commonly used aridity index is the Aridity Index (AI), also known as the De Martonne aridity index (**De Martonne, 1926**), which is calculated as the ratio of mean annual precipitation to the mean annual temperature. The De Martonne aridity index, also known as the Aridity Index (AI), is a commonly used aridity index that is calculated as the ratio of mean annual precipitation to the mean annual temperature (**Thornthwaite, 1955**). The formula for calculating the AI is:

$$AI = \frac{P}{T + 10}$$

Where P is the mean annual precipitation in millimeters, and T is the mean annual temperature in degrees Celsius. Different types of climates are classified based on their aridity using the AI, where arid or semi-arid conditions are indicated by values below 20, semi-humid conditions by values between 20 and 40, and humid conditions by values above 40. Therefore, the application of the De Martonne aridity index is beneficial in classifying various climates and evaluating available water resources in a region. It has a wide range of applications, including agriculture, hydrology, and climate modeling.

Emberger's bioclimatic coefficient (Q2)

Emberger's coefficient (Q2) is a measure of aridity that is often used in the field of biogeography and ecology. It was developed by French botanist Jean-Pierre Emberger in the mid-20th century as a way of characterizing the water deficit in each area. The formula of the Q2 index is (**Vessella and Schirone, 2022**):

$$Q2 = \frac{2000 \times P}{M^2 - m^2}$$

P is the mean annual rainfall (in millimeters); M is the mean maximal temperatures of the warmest month in Kelvin degree; and m is the mean minimal temperatures of the coldest month in Kelvin degree. The formula for converting Celsius to Kelvin is K = °C + 273.15. Different types of climates are classified based on their aridity using the Q2, where barren conditions are indicated by values below 10, arid conditions by values between 10 and 45, semi-arid conditions by values between 45 and 70, subhumid conditions by values between 70 and 110, humid conditions by values between 110 and 150 and humid conditions by values above 150 (**Thornthwaite, 1948**).

Potential evapotranspiration (PET)

Potential evapotranspiration (PET) or reference evapotranspiration (ETo) is the amount of water that would be evaporated and transpired by plants if there was an unlimited supply of water. PET is a measure of the water demand of the atmosphere, and is influenced by factors such as temperature, humidity, wind speed, and solar radiation (**Allen *et al.*, 1998**). PET is an important variable in hydrological modeling and water resource management, as it provides an estimate of the amount of water that is required to meet the demand of vegetation and the atmosphere (**Maidment, 1993**). PET is used in conjunction with actual evapotranspiration (AET) to estimate water use by vegetation and to assess the water balance of a particular region or ecosystem. The calculation of ETo is based on the FAO Penman-Monteith equation, which considers various meteorological parameters, such as temperature, humidity, wind speed, and solar radiation, to estimate the amount of water that would be lost from the reference crop under ideal conditions. To calculate ETo using Cropwat, The Penman-Monteith equation is expressed as follows (**Allen *et al.*, 1998; Jensen *et al.*, 1990**):

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T + 273.16}\right)u2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u2)}$$

Where: ETo is the reference evapotranspiration in millimeters per day, delta is the slope of the saturation vapor pressure curve (kPa/°C), Rn is the net radiation at the Earth's surface ($MJ/m^2/day$), G is the soil heat flux density ($MJ/m^2/day$), gamma is the psychrometric constant (kPa/°C),T is the mean daily air temperature at 2 meters (°C), u2 is the wind speed at 2 meters (m/s), es is the saturation vapor pressure (kPa), ea is the actual vapor pressure (kPa)

Correlation Matrix

A correlation matrix is a table that displays the correlation coefficients between multiple variables. The correlation coefficient measures the strength and direction of the linear relationship between two variables, with values ranging from -1 to 1. A positive correlation coefficient indicates a positive linear relationship, meaning that as one variable increases, the other variable also tends to increase. A negative correlation coefficient indicates a negative linear relationship, meaning that as one variable increases, the other variable tends to decrease. A correlation coefficient of 0 indicates no linear relationship between the variables (**Tabachnick and Fidell, 2007; Hair *et al.*, 2010**). Using R programming language, a correlation matrix was created to investigate the relationships between various variables in a dataset, including maximum and minimum temperatures, precipitation, humidity, number of hours of sunshine, net radiation at the Earth's surface, aridity indices, and ETo. The correlation matrix provides a useful tool for identifying any significant correlations between the variables and exploring the patterns of their relationships.

Climate Zones Delineation Using Cluster Analysis

Climate zones are geographical areas with similar climatic conditions, based on factors such as temperature, precipitation, and vegetation **(Köppen, 1936)**. Climate zones can be defined at various scales, from regional to global, and they are often used in climate research, environmental monitoring, and urban planning **(Trewartha, 1961)**. Climate zones have important implications for human activities and natural systems, as they impact factors such as agriculture, water availability, and biodiversity **(IPCC, 2014)**. Understanding the characteristics and boundaries of climate zones is essential for developing effective policies and management strategies to address climate change and its impacts **(FAO, 2016)**.

Cluster analysis is a statistical technique that involves grouping data points or objects into clusters based on their similarity or dissimilarity **(Everitt *et al.*, 2011)**. The goal of cluster analysis is to identify meaningful patterns or structures in the data, such as natural groupings or clusters of related observations **(Jain *et al.*, 1999)**. Similar meteorological stations were grouped into a cluster using cluster analysis on the data collected from the stations to delineate climate zones then the climate zones were mapping using ArcMap 10.2.1.

RESULTS AND DISCUSSION

Temporal Changes of Annual Meteorological Elements in the Philippines

Boxplot of annual meteorological elements averages in the Philippines

Results in Table 1 and Fig.2. show Boxplot of annual meteorological elements averages, aridity index (AI) and Emberger coefficient (Q2) in the Philippines during the past 30 years (1991-2020) including maximum and minimum temperatures, precipitation, humidity, number of hours of sunshine, and wind speed. The data was displayed using Boxplot.

This trend of results is the same as that of **(Chang *et al.*, 2005)** Temperatures in the Philippines do not vary significantly across different seasons. The coldest month, on average, is January which coincides with the East Asian winter monsoon **(Cruz *et al.*, 2016; Villafuerte *et al.*, 2019)**. While the hottest month is May. Note, however, that the difference in average temperature in the Philippines between the hottest month and the coldest is only about 2.5°C.

However, this trend of results is the same as **(eg, Chang *et al.*, 2005; Bagtasa, 2017; Villafuerte *et al.*, 2017)** average monthly precipitation values in the country. It has been shown that monsoon rainfall in the Philippines behaves differently across the country's climatic regions. and this trend of results is the same as the world bank, the country's wettest months occur during the latter half of the year coinciding to the large-scale monsoon systems. Average annual rainfall is approximately 2,348 millimeters (mm), but this varies geographically, from 960 mm in southeast Mindanao to over 4,050 mm.

The summer monsoon season across the Asian continent typically begins in June and peaks in August (although it may be as early as May and can last into September **(Wang and LinHo, 2002)**. Monsoons contribute about 43%, on average, of Annual rainfall in the Philippines (**Asuncion and Jose, 1980; Cruz *et al.*, 2013**).

Table 1. Annual meteorological elements averages distribution in the Philippines during the past 30 years (1991-2020)

Parameter	Min	Max	Median	Mean	Variance	Standard deviation
Air minimum temperature (°C)	15.3	24.9	23.1	22.9	31.35	5.59
Air maximum temperature (°C)	22.8	33.3	31.2	31.01	38.08	6.17
Air humidity (%)	73	95	82	82.45	296.5	17.22
Wind speed (km/day)	50	360	115	131.6	14892.7	122.03
Sunshine period (hr)	5.3	8	6.1	6.22	2.47	1.57
Radiation (MJ/m^2/day)	16	20	17.85	17.89	27.32	5.23
Reference evapotranspiration (ETo) (mm/day)	3.03	4.5	3.87	3.87	5.13	2.27
Rainfall (mm)	1066.7	4443	2310	2403.3	84.57	9.2
Eff. rainfall (mm)	880.5	1916.4	1342.15	1370.44	75.07	8.664
Vapor press (mbs)	19.3	32.4	30.35	29.95	75.07	8.664
Aridity Index (AI)	28.41	133.5	62.3	65.5	0.135	0.368
Emberger coefficient (Q2)	4060.02	27142.61	11013.1	11407.8	5765.5	75.9

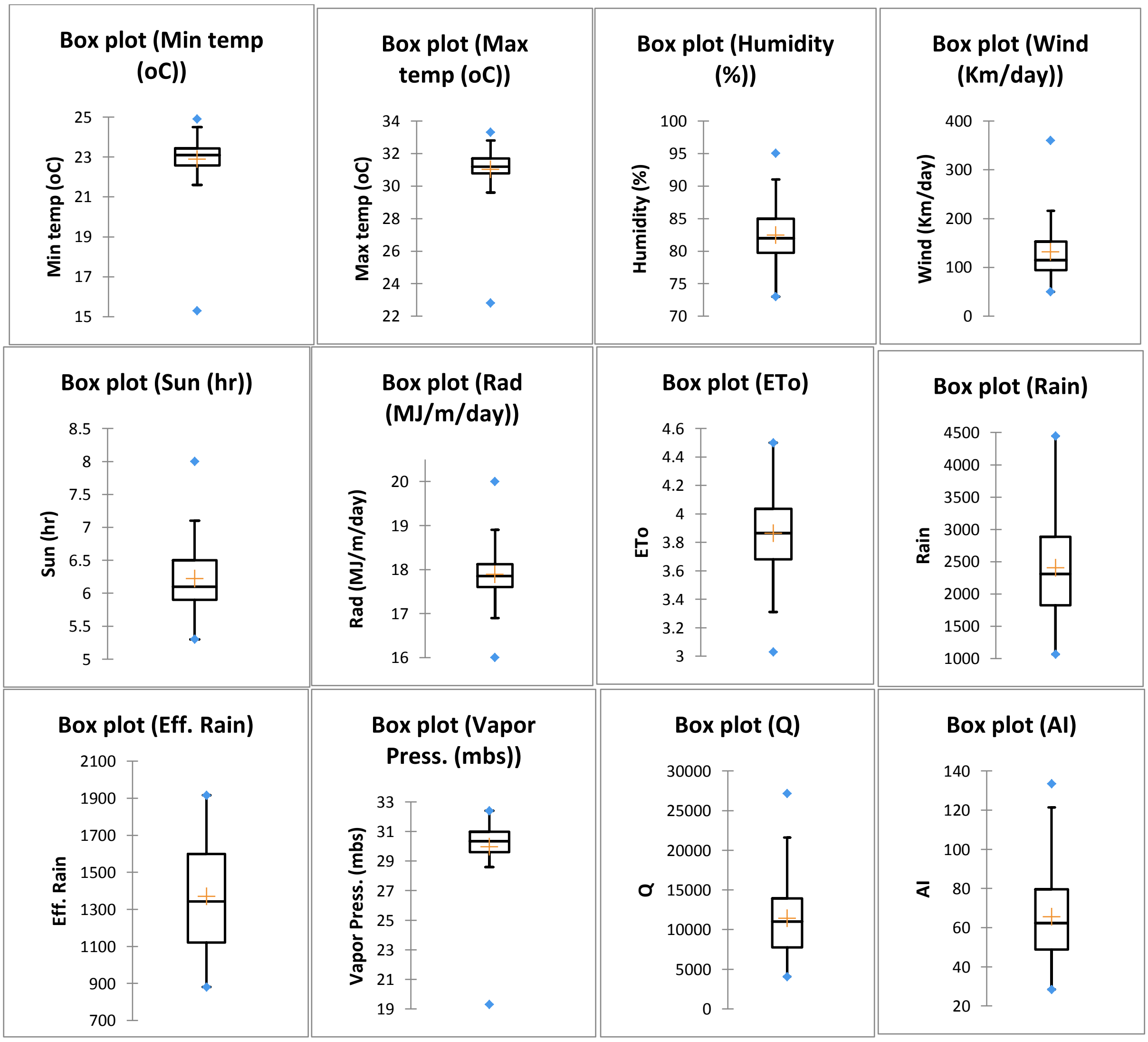


Fig. 2. Boxplot of annual meteorological elements averages, aridity index (AI) and Emberger coefficient (Q2) in the Philippines during the past 30 years

Low-level southwesterly winds prevail throughout the Philippines during this season causing wetter conditions over the western regions of the country.

This resulting orientation for Aridity Index (AI) was the same **(Salvacion, 2021; (Terra Climate, 2021; Hilario, 2009; Holden, 2013; Holden, 2012)**. Publicly available monthly (1958-2019), The magnitude of the drought in the country ranges from 47 to 677 mm and can last from 2 to 11 months and the strength is from 60 to 800 mm/month. Evapotranspiration rate in the Philippines is 2 to 5 mm per day for wet season and 4 to 9 mm per day for dry season.

Correlation Matrix for Philippines

Fig. 3. shown Correlation matrix between studied meteorological elements in Philippines, and the reference evapotranspiration (ETo) in millimeters per day, which the correlation between (ETo) with radiation is 0.9 which indicates that they're strongly positively correlated, and the correlation between (ETo) with sunshine period is 0.72 which indicates that they're positively correlated, the correlation between (ETo) with maximum and aver and minimum air temperatures is (0.71,0.63,0.43) respectively which indicates that they're positively correlated, the correlation between (ET0) with air humidity and rainfall is (- 0.54 ,- 0.35) respectively which indicates that they're weakly negatively correlated.

There is no significant trend in the annual rainfall in the Philippines, which is consistent with the findings of a previous report **(Hilario *et al.*, 2018)**. However, we show that there is a detected regime shift in annual rainfall from 1995 to 2020 (Period 1, $p<0.01$) when compared with 1961–1994 (Period 2). To the extent of our knowledge, such abrupt shift in mean annual rainfall in the Philippines has not been described in known literature yet. Additionally, we show that the annual T_{min} ($p<0.01$) and T_{max} ($p < 0.01$) have significantly increasing trends, respectively.

The annual rainfall is also shown to be positively correlated with annual T_{min} ($r = 0.49$, $p < 0.01$) and negatively correlated with annual T_{max} ($r=- 0.21$, $p = 0.119$) (note again that the slope of T_{min} is higher than T_{max}), respectively. Meanwhile, the annual outgoing longwave radiation (OLR) averaged from 3–20°N 115–130°E is also highly correlated with the observed annual rainfall in the Philippines ($r=-0.95$, $p < 0.01$). The OLR is a heuristic metric than can be used to characterize cloudiness and rainfall where a negative OLR indicates increased overcast and rainfall conditions. Here we show that the annual OLR has a negative correlation with annual T_{min} ($r=-0.50$, $p = 0.001$) while the annual T_{max} has a positive correlation with OLR ($r = 0.33$, $p = 0.043$). An increased in cloud cover, particularly during the daytime, it is shown that the diurnal cycle of rainfall in the Philippines peaks around early to late afternoon **(Natoli and Maloney, 2019; Hilario *et al.*, 2021).** Therefore, it is likely that there have been more overcast conditions during the daytime than at nighttime in the Philippines, which may explain the slower trend of annual T_{max} than annual T_{min}. However, the effect of external forcings including modes of diurnal variability (e.g., solar radiation, clouds) on the long-term trend of sub daily parameters can be a subject for future investigations. Meanwhile, which means that if such detected trend and shift persist then it is likely that the Philippine climate will continue to become wetter with narrower DTR.

Caguiat *et al.* (2022) ad Moran (2018) spatial and temporal ET_o trends were analyzed using the Mann-Kendall test and Sen's slope estimator. Correlation and sensitivity analyses were conducted to analyze the impact of weather variables on ET_o. Positive correlations were observed for maximum temperature, solar radiation, and wind speed whereas negative correlations were observed for relative humidity and minimum temperature.

Climate Zones Delineation Using Cluster Analysis in the Philippines

Climate Types Based on the distribution of rainfall, four climate types are recognized, which are described as follows: Typhoons have a great influence on the climate and weather conditions of the Philippines. A great portion of the rainfall, humidity and cloudiness are due to the influence of typhoons. They generally originate in the region of the Marianas and Caroline Islands of the Pacific Ocean which have the same latitudinal location as Mindanao.

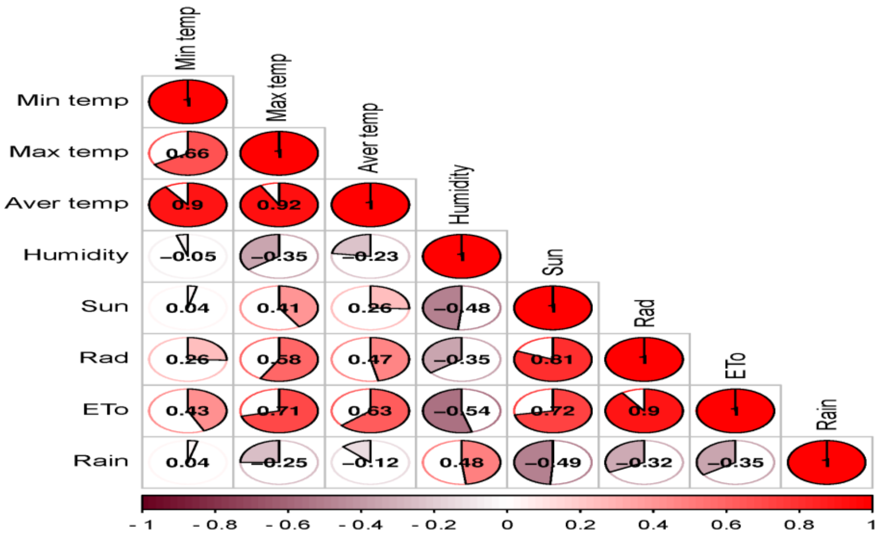
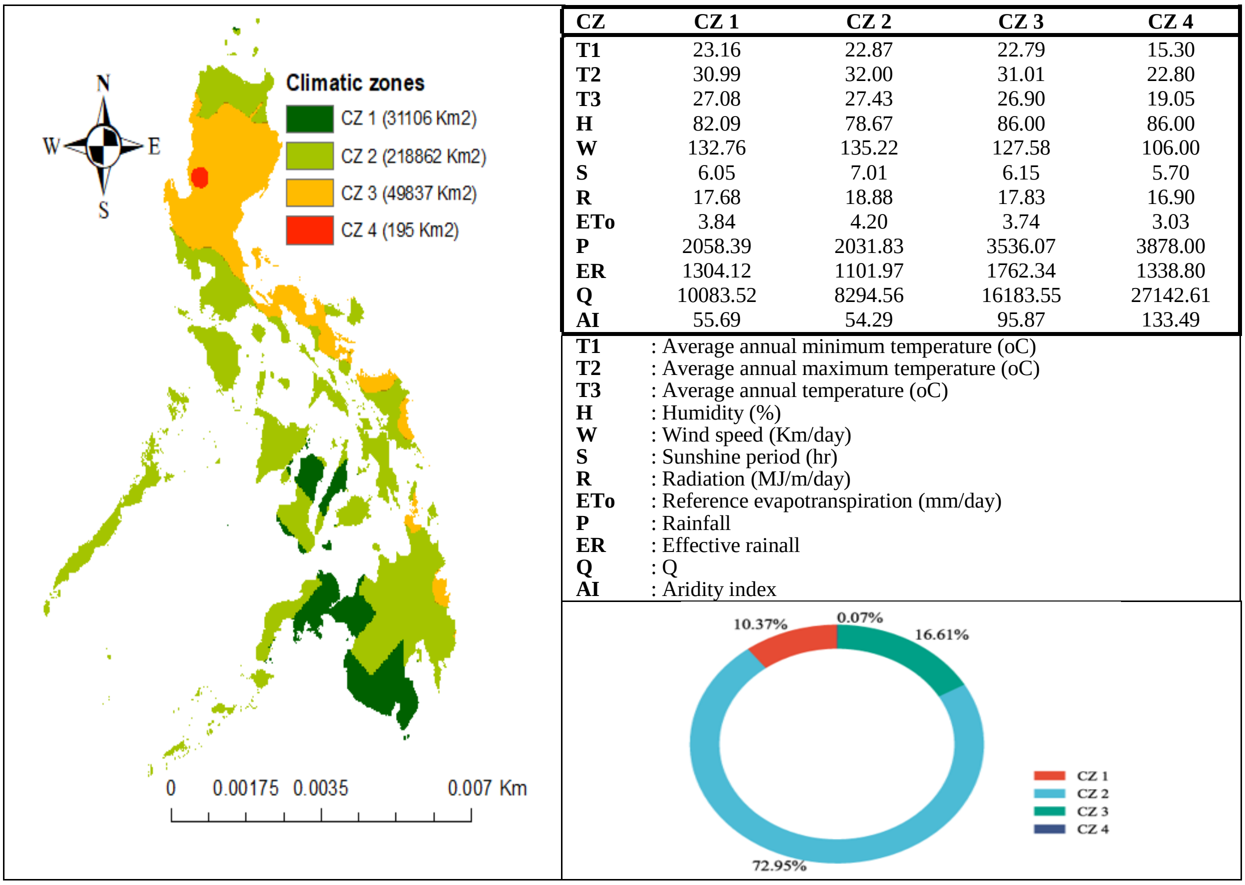


Fig. 3. Correlation matrix between studied meteorological elements, and ETo



CZ	CZ 1	CZ 2	CZ 3	CZ 4
T1	23.16	22.87	22.79	15.30
T2	30.99	32.00	31.01	22.80
T3	27.08	27.43	26.90	19.05
H	82.09	78.67	86.00	86.00
W	132.76	135.22	127.58	106.00
S	6.05	7.01	6.15	5.70
R	17.68	18.88	17.83	16.90
ETo	3.84	4.20	3.74	3.03
P	2058.39	2031.83	3536.07	3878.00
ER	1304.12	1101.97	1762.34	1338.80
Q	10083.52	8294.56	16183.55	27142.61
AI	55.69	54.29	95.87	133.49

T1	: Average annual minimum temperature (oC)
T2	: Average annual maximum temperature (oC)
T3	: Average annual temperature (oC)
H	: Humidity (%)
W	: Wind speed (Km/day)
S	: Sunshine period (hr)
R	: Radiation (MJ/m/day)
ETo	: Reference evapotranspiration (mm/day)
P	: Rainfall
ER	: Effective rainall
Q	: Q
AI	: Aridity index

Fig. 4. Digital map of climatic zones in the Philippines based on meteorological elements, aridity index (AI), Emberger coefficient (Q) and ETo

Their movements follow a north-westerly direction, sparing Mindanao from being directly hit by majority of the typhoons that cross the country. This makes the southern Philippines very desirable for agriculture and industrial development. The figure 4 shows the division of the Philippines into four climatic regions Digital map of climatic zones (CZ) in the Philippines based on meteorological elements, aridity index (AI), Emberger coefficient (Q) and ETo, the 1st climatic zone (CZ 1) includes an area 31106 km^2, percentage 10.37 of the total area of the Philippines. The 2nd climatic zone (CZ2) includes an area 218862 km^2, percentage 72.95. The 3rd climatic -zone (CZ 3) includes an area 49837 km^2 percentage 16.61% and the 4th climatic zone (CZ 4) includes an area 195 km^2 percentage 0.07% covered by a meteorological BAGUIO station (Elevation:1500 m from sea surface).

These results are consistent with many previous results Studies for climatic regions of The Philippine Atmospheric, Geophysical and Astronomical Services Administration **(PAGASA)** currently classifies Philippine climates as **(Coronas, 1912; Flores and Balagot, 1969; Basconcillo *et al.*, 2017).** To introduce the Philippine four types of climates. Climate type (C1) Located in the western coast of the Philippines, the peak rainfall observed is in June, July and August and the dry period is in December, January and February. For a long time on the eastern coasts, C2 does not have a dry season with peak periods of rainfall from September to November. The summer and winter monsoons coincide with the C1 and C2 extreme rainy seasons, respectively. Monsoonal precipitation is similar in C3 and C4a with no clear maximum rainy period, but with relatively dry months of March, April, and May **(Pagassa, 2021a)**.

Conclusions

The Philippines was divided into four weather regions based on data collected from meteorological stations across the regions of Philippines. The first, second, and third climatic zones covered 10.37%, 72.95%, and 16.61% of the total area of the Philippines, respectively. Each zone had different values for various climate indicators. In the first climatic zone, the average annual minimum temperature was 23.16°C, the average annual maximum temperature was 30.99°C, the average annual temperature was 27.08°C, the humidity was 82.09%, the wind speed was 132.76 Km/day, the sunshine period was 6.05 hours, the radiation was 17.68 MJ/m/day, the reference evapotranspiration was 3.84 mm/day, the rainfall was 2058.39 mm, the effective rainfall was 1304.12 mm, the Q value was 10083.52, and the aridity index was 55.69. The second climatic zone had different values, with an average annual minimum temperature of 22.87°C, an average annual maximum temperature of 32.00°C, an average annual temperature of 27.43°C, a humidity of 78.67%, a wind speed of 135.22 Km/day, a sunshine period of 7.01 hours, a radiation of 18.88 MJ/m/day, a reference evapotranspiration of 4.20 mm/day, a rainfall of 2031.83 mm, an effective rainfall of 1101.97 mm, a Q value of 8294.56, and an aridity index of 54.29. The third climatic zone had its own set of values, including an average annual minimum temperature of 22.79°C, an average annual maximum temperature of 31.01°C, an average annual temperature of 26.90°C, a humidity of 86.00%, a wind speed of 127.58 Km/day, a sunshine period of 6.15 hours, a radiation of 17.83 MJ/m/day, a reference evapotranspiration of 3.74 mm/day, a rainfall of 3536.07 mm, an effective rainfall of 1762.34 mm, a Q value of 16183.55, and an aridity index of 95.87. Lastly, the fourth climatic zone had an average annual minimum temperature of 15.30°C, an average annual maximum temperature of 22.80°C, an average annual temperature of 19.05°C, a humidity of 86.00%, a wind speed of 106.00 Km/day, a sunshine period of 5.70 hours, a radiation of 16.90 MJ/m/day, a reference evapotranspiration of 3.03 mm/day, a rainfall of 3878.00 mm, an effective rainfall of 1338.80 mm, a Q value of 27142.61, and an aridity index of 133.49.

REFERENCES

Allen, R.G., L.S. Pereira, D. Raes and M. Smith (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/ docrep/ X0490E/ X0490E00.htm.

Bagtasa, G. (2017). Contribution of tropical cyclones to rainfall in the Philippines. Journal of Climate 30 (10): 3621–3633. https:// doi.org/10.1175/JCLI-D-16-0150.1.

Basconcillo, J.Q., G.A.W. Duran, A.A. Francisco, R.G. Abastillas, F.D. Hilario, E.L. Juanillo, A.S. Solis, A.J.R. Lucero and S.L.A. Maratas (2017). Evaluation of spatial interpolation techniques for operational climate monitoring in the Philippines.SOLA 13, 114–119. https:// doi. org/ 10. 2151/ sola. 2017- 021.

Caguiat, L.S., R.B. Saludes, M.L.Y. Castro and R.M. Lampayan (2022). Spatio-Temporal Trend Analysis of Reference Evapotranspiration in Central Luzon, Philippines. Philippine J. Sci., 152 (S1): 33-46, Philippine Meteorol. Res. ISSN 0031–7683. Date Received:26 Nov 2022.

Chang, C.P., Z. Wang, J. McBride and C.H. Liu (2005). Annual cycle of Southeast Asia–maritime continent rainfall and the asymmetric monsoon transition. J. Climate, 18: 287–301.

Coronas, J. (1912). The extraordinary drought in the Philippines: October 1911 to May 1912. Weather Bureau, Department of the Interior, Government of the Philippine Islands.

Cruz, F.T., H. Sasaki and G.T. Narisma (2016) Assessing the sensitivity of the non-hydrostatic regional climate model to boundary conditions and convective schemes over the Philippines. J. Meteorol. Soc. Japan, 94A: 165–179.

De Martonne, E. (1926). Une nouvelle fonction climatologique: L'indice d'aridité. La meteorologie, 2 (5), 449-458.

Everitt, B.S., S. Landau, M. Leese and D. Stahl (2011). Cluster Analysis. John Wiley and Sons, Ltd. ISBN: 978-0470749913.

FAO (1998). Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/x0490e/x0490e00.htm.

FAO (2016). Climate Change and Food Security: Risks and Responses. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-i6030e.pdf.

Flores, J. and V. Balagot (1969). Climate of the Philippines. Climates of Northern and Eastern Asia. In: World Survey of Climatol., 159–213.

Hair, J.F., W.C. Black, B.J. Babin and R.E. Anderson (2010). Multivariate Data Analysis. Prentice Hall. ISBN: 978-0138132637.

Hilario, F.D., R. De Guzman, D. Ortega, P. Hayman and B. Alexander (2009). El Niño Southern oscillation in the Philippines: Impacts, forecasts, and risk management. Philippine J. Dev., 34 (1): 9–34.

Hilario, F.D., E.L. Juanillo, R.G. de Guzman, T.A. Cinco, M.Q. Villafuerte II, E.D. Ares, J.A. Manalo, W.A. Agustin, K. Aquino and R. Gaspar (2018). Observed Climate Trends and Projected Climate Change in the Philippines. Philippine Atmospheric, Geophysical, and Astronomical Services Administration, Quezon City.

Hilario, M.R.A., L.M. Olaguera, G.T. Narisma and J. Matsumoto (2021). Diurnal characteristics of summer precipitation over Luzon Island, Philippines. Asia-Pacific J. Atmos. Sci. 57, 573–585. https://doi. org/10. 1007/s13143-020- 00214-1.

Holden, W. N. (2013). Neoliberal mining amid El Niño induced drought in the Philippines. J. Geography and Geol., 5(1): 58–77.

Holden, W.N. and D.R. Jacobson (2012). Mining and natural Hazard ulnerability in the Philippines: Digging to development or digging to disaster? (p. 286). Anthem Press. https://doi.org/10.7135/UPO9781843313960.

IPCC (Intergovernmental Panel on Climate Change) (1996a). Climate change 1995 : the IPCC second assessment report, Vol 2: scientific-technical analyses of impacts. Adaptations and mitigation of climate change. Watson RT, Zinyowera MC, Moss RH (eds). Cambridge Univ. Press, Camb.

IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment

Report of the Intergovernmental Panel on Climate Change (Field, C.B.)

Jain, A.K., M.N. Murty and P.J. Flynn (1999). Data clustering: A review. ACM Computing Surveys, 31 (3): 264-323. https://doi.org/10.1145/331499.331504

Jensen, J.R. (2016). Remote Sensing of the Environment: An Earth Resource Perspective. Pearson Ed., Inc. ISBN: 978-0133400467.

Jensen, M.E., R.D. Burman and R.G. Allen (1990). Evapotranspiration and Irrigation Water Requirements. Ame. Soc. Civil Eng., ISBN: 978-0872627523.

Jose, A.M., R.V. Francisco and N.A. Cruz (1993). A preliminary study on the impact of climate variability/change on water resources in the Philippines. PAGASA, Quezon City.

Jose, A.M. (1992). Preliminary assessment of the 1991–1992 ENSO-related drought event in the Philippines. PAGASA, Quezon City.

Köppen, W. (1936). Das geographische System der Klimate. In: Handbuch der Klimatologie (Vol. 1, Part C). Gebruder Borntraeger.

Longley, P.A., M.F. Goodchild, D.J. Maguire and D.W. Rhind (2005). Geographic Information Systems and Science. John Wiley and Sons, Ltd. ISBN: 978- 0470870011.

Maidment, D.R. (1993). Handbook of Hydrology. McGraw-Hill Education.ISBN:978-0070397323.

Moran, D. (2018). How Do Mountains Affect Precipitation? https://www.dtn.com/how-do-mountains-affect-precipitation.

Natoli, M. and D. Maloney (2019). Intraseasonal Variability of the Diurnal Cycle of Precipitation in the Philippines. J. Atmos. Sci., 79: 11. https :// doi. org/ 10. 1175/ JAS-D- 19- 0152.1.

O'Sullivan, D. and D.J. Unwin (2014). Geographic Information Analysis. John Wiley and Sons, Inc. ISBN: 978-1118676950.

Pagassa (Philippine, Atmospheric, Climate of the Philippines) [WWW Document] (2021a) .http:// bagong. Pagassa. dost. gov. ph/ information/clima te-phili ppines. Accessed 9.15. 21.

Riahi, K., D.P. van Vuuren, E. Kriegler, J. Edmonds, B.C. O'Neill, S. Fujimori, N. Bauer, K. Calvin, R. Dellink, O. Fricko, W. Lutz, A. Popp, J.C. Cuaresma, S. KC, M. Leimbach, L. Jiang, T. Kram, S. Rao, J. Emmerling and M. Tavoni (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. In Global Environ. Change, 42: 153–168. Elsevier BV. https://doi.org/10.1016/j.gloenvcha.2016.05.009.

Rogelj, J., A. Popp, K.V. Calvin, G. Luderer, J. Emmerling, D. Gernaat, S. Fujimori, J. Strefler, T. Hasegawa, G. Marangoni, V. Krey, E. Kriegler, K. Riahi, D.P. van Vuuren, J. Doelman, L. Drouet, J. Edmonds, O. Fricko, M. Harmsen and M. Tavoni (2018). Scenarios towards limiting global mean temperature increase below 1.5°C. In Nature Climate Change, 8 (4): 325–332. Springer Science and Business Media LLC. https://doi.org/10.1038/s41558-018-0091-3.

Salvacion, A.R. (2021). Mapping meteorological drought hazard in the Philippines using SPI and SPEI. Spat. Inf. Res., 29: 949–960. https://doi.org/10.1007/s41324-021-00402-9.

Tabachnick, B.G. and L.S. Fidell (2007). Using Multivariate Statistics. Pearson Education, Inc. ISBN: 978-0321312275.

TerraClimate (2021). Climatology Lab. Retrieved March 23, 2021, from http://www.climatologylab.org/terraclimate.html.

Teutschbein, C. and J. Seibert (2012). Bias correction of regional climate model simulations for hydrological climate-change impact studies: Review and evaluation of different methods. J. Hydrol., 456–457: 12–29. Elsevier BV. https://doi.org/10.1016/j.jhydrol. 2012.05.052.

Thornthwaite, C.W. (1948). An approach toward a rational classification of climate. Geographical Rev., 38 (1): 55-94. https://doi.org/10.2307/210739.

Thornthwaite, C.W. and J.R. Mather (1955). The water balances. Publications in Climatol., 8 (1): 1-104.

Trewartha, G.T. (1961). An Introduction to Climate. McGraw-Hill Education. ISBN: 978-0070652373.

Turco, M., J. von Hardenberg, A. AghaKouchak, M.C. Llasat, A. Provenzale and R.M. Trigo (2017). On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. In Scient. Reports, 7: 1. Springer Sci. and Business Media LLC. https://doi.org/ 10.1038/s41598-017-00116-9.

Van der Schrier, G., J. Barichivich, K.R. Briffa and P.D. Jones (2013). A scPDSI-based global data set of dry and wet spells for 1901-2009. J. Geophysical Res.: Atmospheres, 118 (10): 4025-4048. https://doi.org/10.1002/jgrd.50355.

Vessella, F. and B. Schirone (2022). Forest Conservation and Restoration Using the Emberger Index: Cork Oak as Study Case. Forests, 13(2), 252.

Vicente-Serrano, S.M., S. Beguería and J.I. López-Moreno (2010). A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. J. Climate, 23 (7): 1696-1718. https:// doi.org/10.1175/2009JCLI2909.1.

Villafuerte, M.Q., E.L. Juanillo and F.D. Hilario (2017) Climatic insights on academic calendar shift in the Philippines. Philippine J. Sci., 146 (3): 267– 276.

Villafuerte, M.Q.II., I. Macadam, J. Daron, J. Katzfey, T.A. Cinco, E.D. Ares and R.G. Jones (2019). Projected changes in rainfall and temperature over the Philippines from multiple dynamical downscaling models. In Int. J. Climatol., 40 (3): 1784–1804. Wiley. https://doi.org/10.1002/joc.6301.

Wang, B. and H. Lin (2002) Rainy season of the Asian–Pacific summer monsoon. J. Climate, 15: 386–398.

استخدام تكنولوجيا نظم المعلومات الجغرافية لرسم خرائط المناطق المناخية المحلية: دراسة حالة للفلبين

إبراهيم عبدالصمد إبراهيم بلاطة[1] - إسماعيل محمد عبد الحميد [2] – محمد ممدوح الفقي [2]

1- مركز الطوارئ مصلحة الميكانيكا والكهرباء - وزارة الموارد المائية والري - مصر.

2- الموارد الطبيعية كلية الدراسات الآسيوية العليا - جامعة الزقازيق - مصر.

تركز هذه الدراسة على الفلبين، وهي دولة في جنوب شرق آسيا تبلغ مساحتها حوالي 300.000 كيلومتر مربع، وتضم 7.641 جزيرة، وموقعها الجغرافي بين خطي عرض 4° 40' و21° 10' شمالًا وخطي عرض 116° 40' و126'. ° 34' خط الطول شرقا في جنوب شرق آسيا. يهدف في هذا البحث إلى تحليل تأثير تغير المناخ على موارد المياه السطحية في الدولة. ولتحقيق هذا الهدف، سنقوم بتقييم توزيع درجات الحرارة وهطول الأمطار في مناطق مختلفة من الفلبين، ودراسة التأثيرات الحالية لتغير المناخ على موارد المياه السطحية، والتنبؤ بالآثار المستقبلية لتغير المناخ على موارد المياه السطحية. تم جمع البيانات المتعلقة بالمتغيرات المناخية الشهرية للفلبين من 57 محطة أرصاد جوية، تغطي الفترة من 1991 إلى 2020. وشملت المتغيرات درجة حرارة الهواء (الصغري والعظمي)، وسرعة الرياح، ورطوبة الهواء، وفترة سطوع الشمس، والإشعاع، وهطول الأمطار. وكانت مصادر هذه البيانات هي إدارة الخدمات الجوية والجيوفيزيائية والفلكية الفلبينية (PAGASA) للفلبين، بالإضافة إلى قواعد بيانات CLIMWAT. تم إنشاء الرسوم البيانية لتصور التغييرات مع مرور الوقت في محطات الطقس. وتم رسم البيانات باستخدام Boxplot. وتم حساب مؤشر الجفاف لتصنيف المناخات المختلفة وتقييم الموارد المائية المتاحة في الفلبين. للمناطق الجغرافية ذات الظروف الجوية المماثلة. وتم حساب مقياس الجفاف كوسيلة لوصف نقص المياه في كل منطقة. يبلغ المتوسط السنوي للتبخر والنتح المرجعي للمياه (ETo) في الفلبين (3.87 ملم/يوم). ومعامل الارتباط بين التبخر المرجعي (ETo) والإشعاع الشمسي هو 0.9 مما يدل على أنهما مرتبطان بقوة موجبة، كما أن الارتباط بين (ETo) مع فترة سطوع الشمس ودرجات الحراره الهواء (الصغري والعظمي) (0.72، 0.71، 0.63، 0.43) على التوالي. مما يشير إلى أنهما مرتبطان بشكل إيجابي. وخلصت النتائج إلى أن الفلبين مقسمة إلى أربع مناطق مناخية.

الكلمات الإسترشادية: التغيرات المناخية، هطول الأمطار، درجة الحرارة، التبخر المرجعي، الموارد المائية، الفلبين.

المحكمـــــون:

1- أ.د. جمال الدين مصطفى محمد	أستاذ الميكروبيولوجيا الزراعية المتفرغ – كلية الزراعة – جامعة الزقازيق.
2- أ.د. محمـــــد كمـــــــــــال	أستاذ الأراضي – كلية الزراعة – جامعة الزقازيق.