Open Access
2021, Vol. 18 No.2 (Suppl. June)

Baghdad Science Journal

P-ISSN: 2078-8665
E-ISSN: 2411-7986

DOI: https://dx.doi.org/10.21123/bsj.2021.18.2(Suppl.).1030

Future Scenario of Global Climate Map change according to the Köppen - Geiger Climate Classification

Fahmy Osman Mohammed[1]* *Anwar Othman Mohammad*[2] *Hivi Shawket Ibrahim*[3]
Rozhgar Abdullah Hasan[4]

[1]Geology department, College of Science, University of Sulimani, Sulimani, Iraq
[2]Natural Resources department, College of Agricultural Engineering Science, University of Sulimani, Sulimani, Iraq
[3]Horticulture department, College of Agricultural Engineering Science, University of Sulimani, Sulimani, Iraq
[4]Natural Resources department, College of Agricultural Engineering Science, University of Sulimani, Sulimani, Iraq
Correspondent author: fahmy.mohammed@univsul.edu.iq, anwar.mhamad@univsul.edu.iq, hivi.ibrahim@univsul.edu.iq, rozhgar.hasan@univsul.edu.iq
*ORCID ID: https://orcid.org/0000-0003-3755-0949 *, https://orcid.org/0000-0003-4082-5974[2] , https://orcid.org/0000-0002-8282-9853[3] , https://orcid.org/0000-0003-0097-8327[4]

Received 19/9/2020, Accepted 3/2/2021, Published 20/6/2021

Abstract:
Earth's climate changes rapidly due to the increases in human demands and rapid economic growth. These changes will affect the entire biosphere, mostly in negative ways. Predicting future changes will put us in a better position to minimize their catastrophic effects and to understand how humans can cope with the new changes beforehand. In this research, previous global climate data set observations from 1961-1990 have been used to predict the future climate change scenario for 2010-2039. The data were processed with Idrisi Andes software and the final Köppen-Geiger map was created with ArcGIS software. Based on Köppen climate classification, it was found that areas of Equator, Arid Steppes, and Snow will decrease by 3.9 %, 2.96%, and 0.09%, respectively. While the areas of Warm Temperature and Dessert will increase by 4.5% and 0.75%, respectively. The results of this study provide useful information on future climate Köppen-Geiger maps and areas that will most likely be affected by climate change in the following decades.

Key words: Biomass, Climatic zones, Idrisi Andes software, Land surfaces, Vegetation

Introduction:
Global climate classifications were developed to distinguish the climates into a number of types (1) based on climate's individual elements, such as precipitation, temperature, wind, vegetation distribution, and atmospheric pressure (2, 3). Climate classifications are established to display the mean spatial climate characteristics; also, it is used to identify climatic types (4). There are two classification systems: the empirical that uses statistical data and the genetic that uses causal factors to classify. The most used method for climate classification (5) is the Köppen Climate Classification developed in 1900 (5) by the plant physiologist Wladimir Köppen. Natural vegetation is used by Köppen as an index for different climates (6). Köppen suggested the first scheme in the description of climatic types based on numerical limits of temperature and precipitation that represented the ecological margin of similar flora (2). Five basic climate types have been distinguished (7). These types are presented via the first five letters of the alphabet: (A) for the equatorial zone, (B) for the arid zone, (C) for the warm zone, (D) and (E) t for the snow zone and polar zone respectively. The climate subtypes are symbolized by a second or a third letter, depending on which parameter is taken into consideration for the classification (6). The global mean surface temperature has risen by about 0.5 °C over the last 100 years (8), and global average surface air temperature, which is affected by land cover, vegetation phenology, anthropogenic effects, and geology (9) is projected to increase climate change in different regions of the globe in a different way (10) This classification is based on two parameters: the annual cycles of precipitation and temperature (7). Surface air temperature is the most commonly used climate change parameter (11), and together with precipitation are the two elements that affect our environment more noticeably and directly lead to reduce lakes ice cover in the world (1-12). This method also takes into concern the potential of

evapotranspiration and its importance for the climate and relations between heat and moisture through applied logical and mathematical equations (1).

Previous studies have used this classification for several purposes. Baker et al., (11) have used Köppen classification through multivariate techniques to evaluate the climate changes in the ecoregions of China. Nistor and Mîndrescu (13) used climate change classification to assess groundwater resources. Furthermore, previous studies updated the Köppen-Geiger world map climate classification (3-6) and applied it to confirm general circulation control model runs of present climate and greenhouse gas warming simulations.

In the current research, a future scenario generated in order to produce a future map based on SRES (Special Report on Emissions) A1B emission scenario (14-15) that assume: “a future world with a fast-economic growth, low population growth and the expiation of using new and more advanced technology. However, the major underlying themes are economic, cultural convergence, and capacity building, with a reducing regional difference in per capita income. In a world where people work for individual wealth rather than the quality of environmental.” In addition, the past decade available data used for the creation of a second world map, including real measurements and a high-resolution grid.

The work aimed to create two climate zones maps for past and future based on available temperature and precipitation data for the thirty years (1960-1990) in the past and thirty years (2010 – 2039) future predicted data based on SRES A1B scenario, then compare and calculate the area of the climate zones.

Data and Methods

Two global datasets of climate observations regarding the past data and the future scenario-providing climate modeled datasets have been selected for this research. All the data are obtained from the Intergovernmental Panel on Climate Change (IPCC) are available on www.ipcc-data.org/. Monthly precipitation and temperature observations for the past 30 years from the Climate Research Unit, CRU of the University of East Anglia, are obtainable on a 0.5-degree latitude/longitude grid resolution and cover the global land areas excluding Antarctica. These data cover a period of 30 years, from 1961 to 1990. Future precipitation and temperature scenario data (SRES A1B Emissions Scenarios) are available on a 2.81 degrees’ latitude/longitude grid, with monthly resolution and excluding Antarctica. These data cover 30 years, from 2010 to 2039. All data above have been processed with the GIS analytical tool land change modeler IDRISI Andes software (version 15.00). The software provides a rapid quantitative assessment of change by graphing gains and losses by land cover categories, and the final maps were created and processed in Geographic information system ArcGIS software (version 10.8). The calculation of Köppen classes' classification was as follows, the main climate classes, represented by one or two letters depending on the climate differences described in Table 1.

In Table 1 (Köppen classification), the first letter represents the main class and the second one, the subclass. These summed seven different possible climate classes that are used in this study. The classes A, C, and D are not divided into any subclasses; therefore, they will not be considered. Classes B and E have been divided into the subclasses BS (Steppe climate), BW (Desert climate), ET (Tundra climate) and EF (Frost climate). Köppen and Geiger observed that in a large areal amount, not all of the subclasses occur, and not all the class types had the same climatological importance(9); accordingly, in the present article, just seven classes have been taken into account. In Table 1 (Köppen classification), the first letter represents the main class and the second one, the subclass. These summed seven different possible climate classes that are used in this study.
Climatology was calculated by adding separately all years’ months and dividing them by 30. For example, the climatology of the temperature of January (for the past) should be calculated as (Jan. "61 + Jan. "62 + …+ Jan. "90)/30, which finally produces the mean –30 years – temperature value for the selected month.

Table 1. Köppen and Geiger classification key, the formula for the main climate classes. The details about each criterion are given in the text.

Type	Description	Criterion
A	Equatorial Climate	$T_{min} \geq +18$ °C
B	Arid climate	$P_{ann} < 10\ P_{th}$
BS	Steppe climate	$P_{ann} > 5\ P_{th}$
BW	Desert climate	$P_{ann} \leq 5\ P_{th}$
C	Warm Temperature climate	-3°C $< T_{min} < +18$ °C and $T_{max} > 10$ °C
D	Snow climates	$T_{min} \leq -3$ °C
E	Polar climate	$T_{max} \leq +10$ °C
ET	Tundra climate	0 °C $\leq T_{max} < +10$ °C
EF	Frost climate	$T_{max} < 0$ °C

These mean values are used as the monthly mean temperature and precipitation values. In Table 1, P_{ann} denotes the annual mean precipitation, T_{max}

the monthly mean temperature of the warmest month, and T_{min} the monthly mean temperature of the coldest month. All temperatures are given in degree Celsius (°C), precipitation in cm/month, and annual precipitation in cm/year.

Additionally, P_{th} (dryness threshold) was calculated in cm regarding the arid climates (B class), which depend on absolute | Tann |, The absolute value of the mean annual temperature, and on the yearly period of precipitation (9). After completing those calculations, the classes and subclasses A, C, D, EF, and ET have been created, based on the criteria from Table 1. Antarctica is not included within the data sets, and therefore, this region is also excluded from the analyses presented here, but it is reported as a polar frost climate (EF) in the (9) study.

For the creation of the arid class (B) and its subclasses (BW and BS), the criteria from Table 1 and equation (Eq.1) were used. The global data divided into two hemispheres, separating the South and North winter and summer respectively, and afterward, the hemispheres merged, based on the correct season.

All the separate maps created from the previous steps were finally added together, composing the final global past and future maps, these presented in the results.

$$P_{th} = \begin{cases} 2\{T_{ann}\} & \text{if at least } 2/3 \text{ of the annual Precipitation occurs in the winter.} \\ 2\{T_{ann}\}+28 & \text{if at least } 2/3 \text{ of the annual precipitation occurs in the summer.} \\ 2\{T_{ann}\}+14 & \text{Otherwise} \end{cases}$$

-----------1 (9)

Results:

Two different sets of data (resolution) used 2.81 degrees (approximately more than 300 Km^2 for each pixel size) and 0.5 degrees (approximately more than 55 Km^2 for each pixel size) latitude/longitude grid in this research; this is because the data for future scenario (A1B SERS) was only available on a regular 2.81-degree latitude/longitude grid.

Figure 1 presents a world map produced from the mean monthly temperature and precipitation data according to Köppen climate classification, for the period 1961 to 1990 on a regular 0.5-degree latitude/longitude grid later it was changed to 2.81-degree resolution Figure 2 as in future data Figure 3 in order to compare and calculate the accurate area for climate zones Figures 4 and 5, the future data set were only available in 2.81 degrees.

Figures 2 and 3 show the world maps resulting from the Köppen-Geiger climate classification using mean monthly temperature and precipitation data for the periods 1961 to 1990 and 2010-2039, respectively, on a regular 2.81degree latitude/longitude grid. All seven-climate classes are illustrated with different colors. Data for Antarctica were not available, and the Antarctic region has been set manually to the ocean. The resulting world maps in Figs. 2 and 3 for 30 years past and future respectively, show how the classes" boundary is and how the area of each class changes, the climate prediction for the future is based on past data and general trends of temperature and precipitation change.

In the graph presented in Fig. 4, the area (km^2) of each class in the past and the future are reported. In some cases, like A, C, and BS class, the difference is significant, and in some others, such as D and ET class, no significant alteration was found. The calculated percentages show that A-class will decrease by 3.9% as well as the BS class by 2.96%. A slight reduction could predict for the D class by 0.09%. Class C will have a more considerable increase by 4.5, while classes ET, BW, and EF are increased by 0.15%, 0.75%, and 0.85% respectively as shown in Fig. 5.

Discussion:

Sparovek, et al. (5) suggested that specific tools of Geographical Information System (GIS) software can improve the accuracy and quality of the maps created for the Köppen climate classification and; it also used to intraplate more parameter like river pattern with Köppen-Geiger climate zone for creating new climate classification like hydroclimate zones (16). Köppen Climate Classification is considered a very old method for climate classification but still is the most valuable method (6), and it is more likely to be used for another century (11).

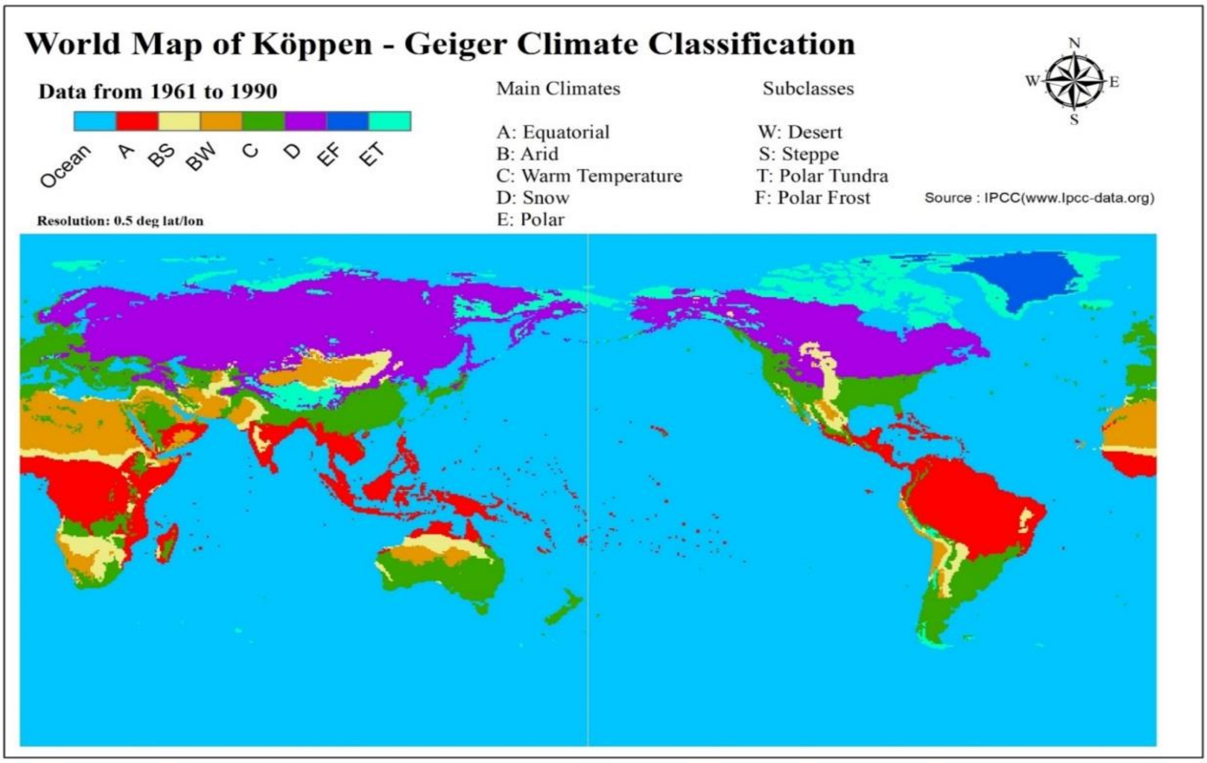


Figure 1. Köppen-Geiger world map climate classification updated with mean monthly SRES A1B temperature and precipitation data for the period 1961 to 1990.

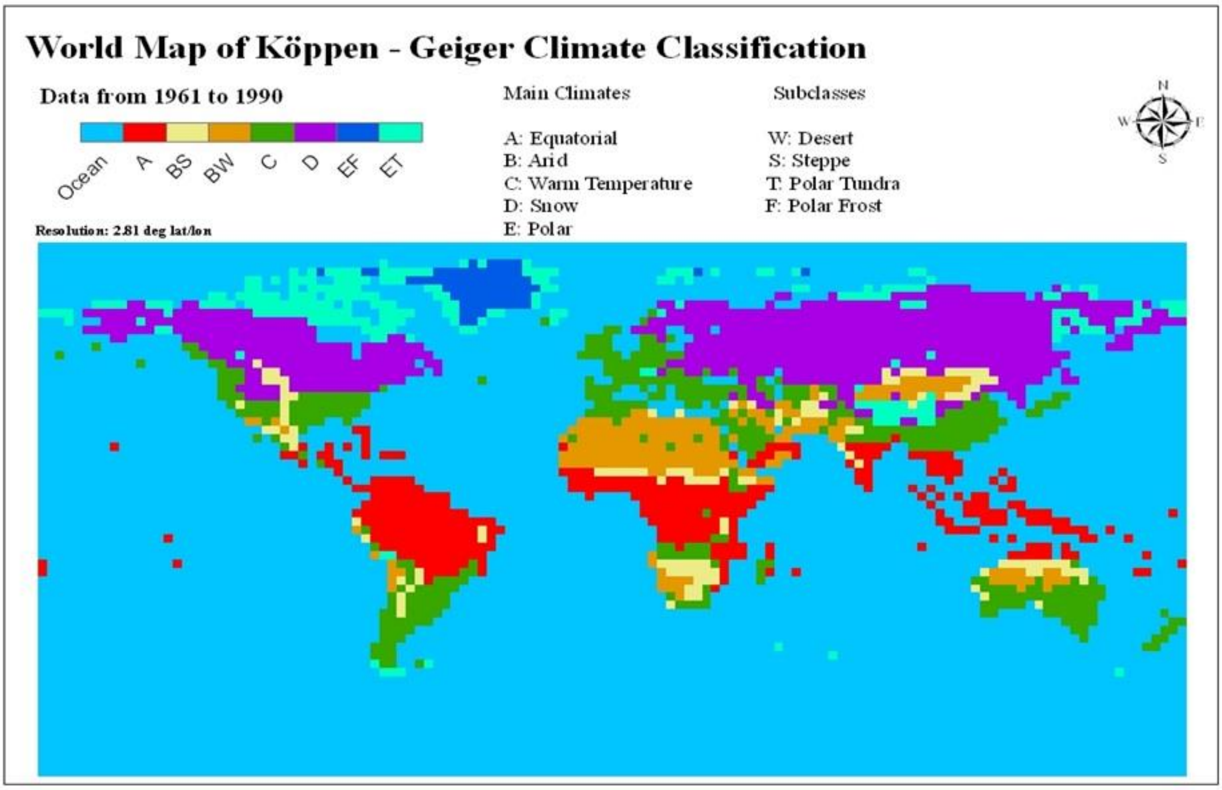


Figure 1. Köppen-Geiger world map climate classification updated with mean monthly SRES A1B temperature and precipitation data for the period 1961 to 1990 on a regular 2.81 degree.

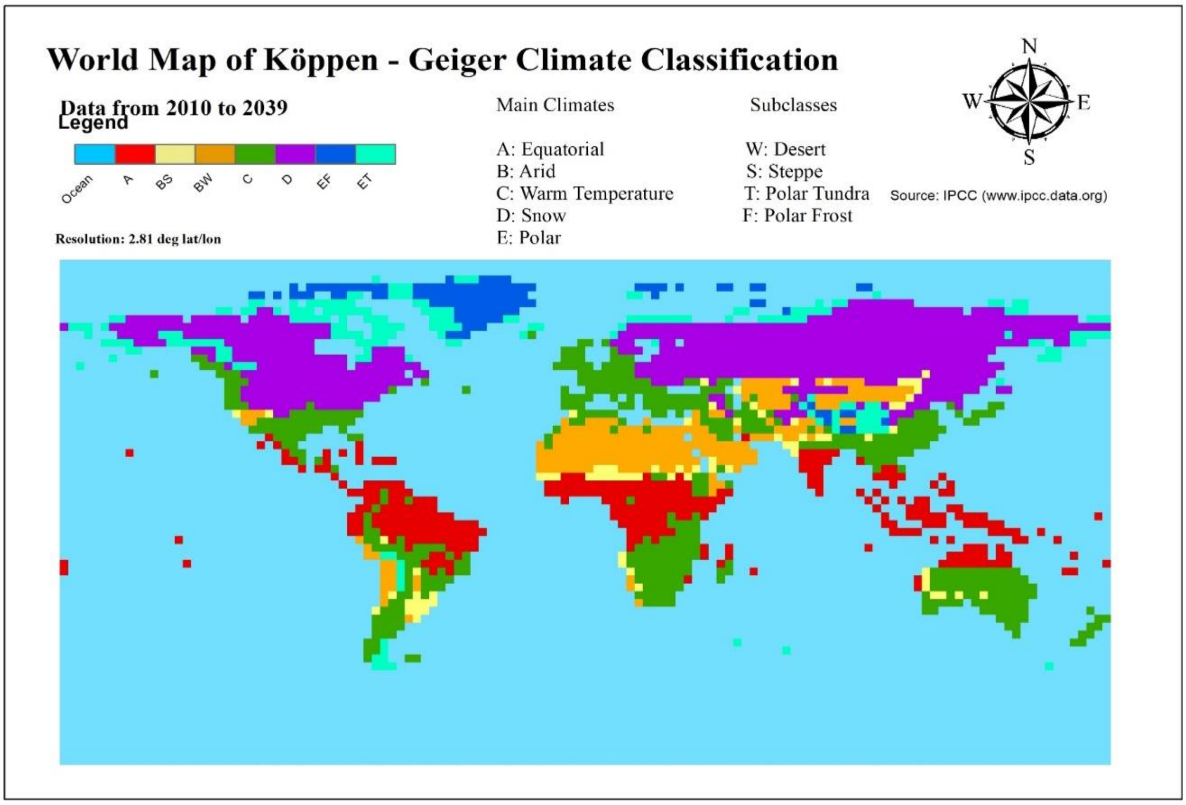


Figure 3. Future World Map of Köppen-Geiger climate classification updated with mean monthly SRES A1B temperature and precipitation data for the period 2010 to 2039 on a regular 2.81-degree latitude/longitude grid.

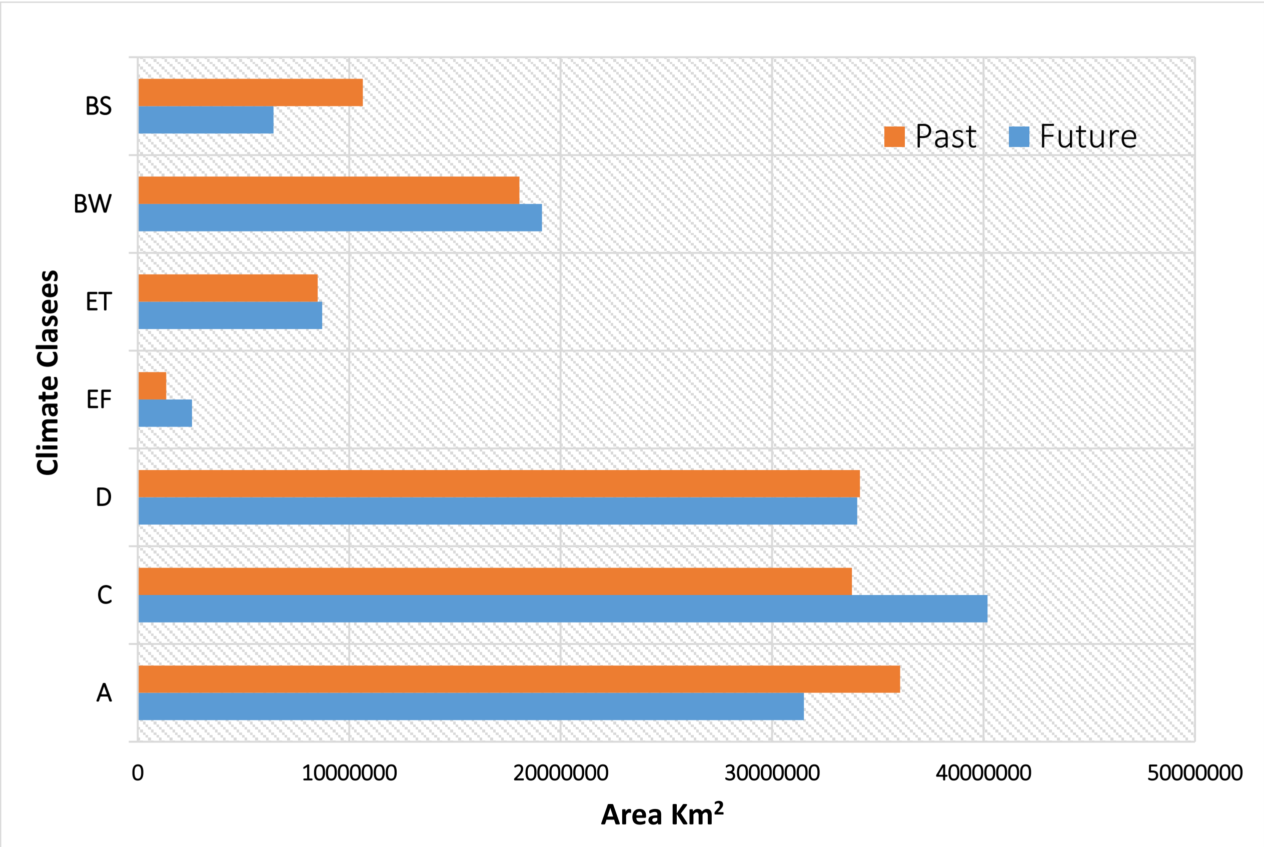
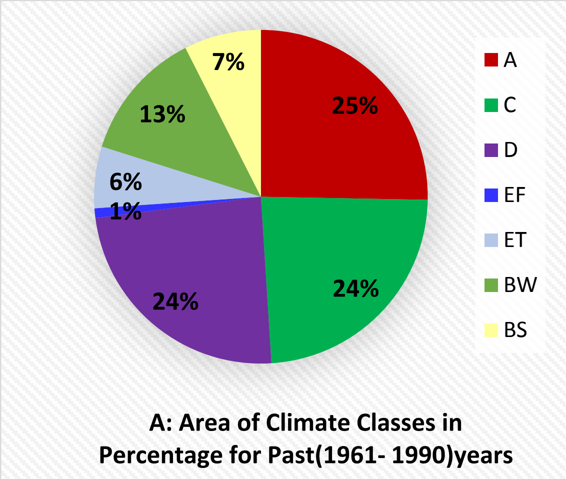


Figure 2. Area calculation for both past and future climate zone



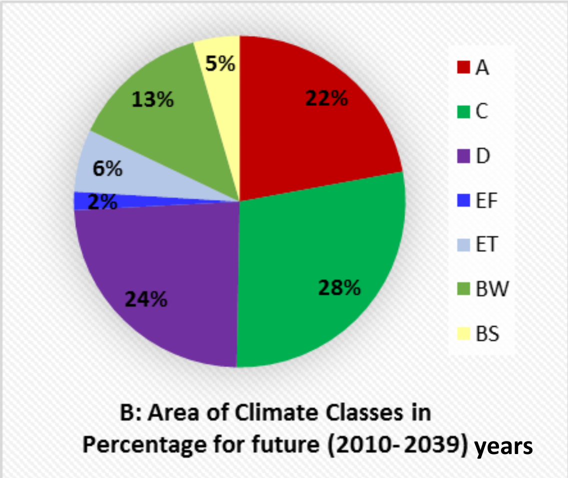


Figure 3. A) The percentage of the area for climate classes in past and B) The percentage of the area for climate classes in the future.

In the current article, Köppen Climate Classification is used to create a detailed world climate map, based on observed and predicted data sets, for the past and future 30 years. Previous studies, such as (8), (17) and (18) have used this classification to produce corresponding updated world maps. Furthermore, other researchers have used past data, modeled future data and paleoclimate data to observe Arctic climate alterations (19, 20).

In this article, the period 1961-1990 has been used as the "past 30 years' period" for the climate classification-model. When the past 30 years are mentioned in the article, the gap of 20 years should be considered. Not until recently, there have been other updates of this climate classification-model; even though the data is from the past three decades, it is still considered to emulate the present reasonable period (6).

Past and expected future scenario's temperature and precipitation data have been used to create the seven climate classes and subclasses of the classification. The additional four subclasses (BS, BW, ET, and ET) that are the polar and arid subclasses were chosen to be calculated, so a comparison between the two threshold climates of the earth could be possible. This comparison revealed that the areas of Equatorial (A), Arid Steppe (BS) and also Snow (D) climates will decrease and, in some cases, this could be explained by the increase of the temperature (19, 21). On the other hand, areas of Warm Temperature (C), Dessert Polar Frost (EF) climate might be a software error. In comparison with other similar studies about climate change and global warming (19) suggested that this error could be as a software, a user, or a dataset error.

Conclusion

A climate change prediction is indispensable for the development of robust climate adaptation plans. The results of this study provide useful information on future climate Köppen - Geiger maps and areas that will most likely be affected by climate change in the following decades. The dessert area will increase by 4.5 %, while the equator and arid steppes zone will decrease by 3.9 % and 2.96%, respectively. These changes will directly affect human wellbeing by altering the availability of freshwater, land-use, and food production across the world.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Besides, the Figures and images, which are not ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at the University of Sulimani.

References:

1. Tapiador FJ, Moreno R, Navarro A, Sánchez JL, García-Ortega E. Climate classifications from regional and global climate models: Performances for present climate estimates and expected changes in the future at high spatial resolution. Atmos Res. 2019; 228(1):107-121. doi: 10.1016/j.atmosres.2019.05.022
2. Köppen W, Grundriß der Klimakunde. De Gruyter, Walter de Gruyter. Berlin, Germany 1931; p. 388 doi: 10.1515/9783111667751
3. Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF. Present and future Köppen-Geiger climate classification maps at 1-km resolution. Sci. Data. 2018; 5(1), Art. no. 180214. doi: 10.1038/sdata.2018.214.

4. Gallardo C, Gil V, Hagel E, Tejeda C, de Castro M. Assessment of climate change in Europe from an ensemble of regional climate models by the use of Köppen–Trewartha classification. Int J Climatol. 2013; 33(9): 2157–2166. doi: 10.1002/joc.3580.
5. Sparovek G, De Jong Van Lier Q, Dourado Neto D. Computer assisted Koeppen climate classification: a case study for Brazil. Int J Climatol. 2007; 27(2): 257–266. doi: 10.1002/joc.1384.
6. Kottek M, Grieser J, Beck C, Rudolf B, Rubel F. World map of the Köppen-Geiger climate classification updated. Metz. 2006; 15(3): 259–263. doi: 10.1127/0941-2948/2006/0130.
7. Lohmann U, Sausen R, Bengtsson L, Cubasch U, Perlwitz J, Roeckner E. The Köppen climate classification as a diagnostic tool for general circulation models. Clim. Res. 1993; 3(3): 177–193.
8. Folland CK, Karl TR, Jim Salinger M. Observed climate variability and change. Weather. 2002; 57(8):269–278. doi: 10.1256/004316502320517353.
9. Bechtel B. A New Global Climatology of Annual Land Surface Temperature. Remote Sens. 2015; 7(3) Art. no. 3. doi: 10.3390/rs70302850.
10. Portmann RW, Solomon S, Hegerl GC. Spatial and seasonal patterns in climate change, temperatures, and precipitation across the United States. Proceedings of the National Academy of Sciences. 2009; 106(18): 7324–7329. doi: 10.1073/pnas.0808533106.
11 Baker B, Diaz H, Hargrove W, Hoffman F. Use of the Köppen–Trewartha climate classification to evaluate climatic refugia in statistically derived ecoregions for the People’s Republic of China. Clim Change. 2010; 98(1): 113. doi: 10.1007/s10584-009-9622-2.
12. Woolway RI, Merchant CJ. Worldwide alteration of lake mixing regimes in response to climate change. Nat Geosci. 2019; 12(4): 271-276. doi: 10.1038/s41561-019-0322-x.
13. Nistor MM, Mîndrescu M. Climate change effect on groundwater resources in Emilia-Romagna region: An improved assessment through NISTOR-CEGW method. Quat Int. 2019; 504(10): 214–228. doi: 10.1016/j.quaint.2017.11.018.
14 Intergovernmental Panel on Climate Change (IPCC). Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies; IPCC Expert Meeting Report: Geneva: IPCC, Switzerland, 2008.
15. Han G, Ma Z, Long Z, Perrie W, Chassé J. Climate Change on Newfoundland and Labrador Shelves: Results From a Regional Downscaled Ocean and Sea-Ice Model Under an A1B Forcing Scenario 2011–2069. Atmos.-Ocean. 2019; 57(1):3–17. doi: 10.1080/07055900.2017.1417110.
16. Hansford MR, Plink-Björklund P, Jones ER. Global quantitative analyses of river discharge variability and hydrograph shape with respect to climate types. Earth-Sci Rev. 2020; 200(1). 102977. doi: 10.1016/j.earscirev.2019.102977.
17. Kushnir Y, Scaife AA, Arritt R, Balsamo G, Boer G, Doblas-Reyes F, et al. Towards operational predictions of the near-term climate. Nat Clim. Change. 2019; 9(2):94–101. doi: 1038/s41558-018-0359-7
18. Her Y, Yoo SH, Cho J, Hwang S, Jeong J, Seong C. Uncertainty in hydrological analysis of climate change: multi-parameter vs. multi-GCM ensemble predictions. Sci Rep. 2019; 21; 9(1):1-22. doi: 10.1038/s41598-019-41334-7
19. Johannessen OM, Bengtsson L, Miles MW, Kuzmina SI, Semenov VA, Alekseev GV, et al. Arctic climate change: observed and modelled temperature and sea-ice variability. Tellus A. 2004; 56(4):328–341, doi: 10.3402/tellusa. v56i4.14418.
20. Friesen TM, Finkelstein SA, Medeiros AS. Climate variability of the Common Era (AD 1–2000) in the eastern North American Arctic: Impacts on human migrations. Quat Int. 2020; 549 (30):142–154, doi: 10.1016/j.quaint.2019.06.002.
21. Change, Intergovernmental Panel On Climate. Climate change 2007: The physical science basis: summary for policymakers. Geneva: Geneva: IPCC, 2007.

السيناريو المستقبلي لتغير خريطة المناخ العالمي وفقا لتصنيف المناخ كوبن جيجر

فهمي عثمان محمد[1] انور عثمان محمد[2] هيڤي شوكت ابراهيم[3] روژگارعبدالله حسن[4]

[1] قسم علوم الارض، كلية العلوم، جامعة السليمانية، السليمانية ، العراق.
[2] قسم الموارد الطبيعية، كلية علوم الهندسة الزراعية، جامعة السليمانية، جامعة السليمانية ، السليمانية ، العراق.
[3] قسم البستنة، كلية علوم الهندسة الزراعية، جامعة السليمانية ، السليمانية ، العراق.
[4] قسم الموارد الطبيعية، كلية علوم الهندسة الزراعية، جامعة السليمانية ، السليمانية ، العراق.

الخلاصة:

يتغير مناخ الارض بسرعة كبيرة بسبب الزيادة في عدد السكان وسرعة النمو الاقتصادي. هذه التغيرات غالبا ستؤثر بشكل سلبي على الغلاف الحيوي . ان التنبؤ بالتغيرات المستقبلية سيضعنا في افضل وضع للتقليل من التأثيرات الكارثية وكيف يمكن للانسان ان يتعامل مع هذه التغيرات مسبقا. استخدمنا في هذا البحث بيانات مناخية سابقة للفترة بين 1961-1990 للتنبؤ بسيناريو التغيرات المناخية المستقبلية للفترة 2010-2039. تمت معالجة البيانات باستخدام برنامج (ادريسي انديز) وخريطة لكوبن - جيجر تم إنشاؤها باستخدام برنامج (أرك جي أي أس). استنادًا إلى التصنيف المناخي لكوبن ، وجدنا أن مناطق خط الاستواء والسهول القاحلة و المناطق الثلجية سوف تقل بنسبة 3.9% و 2.96% و 0.09% على التوالي . بينما المناطق الدافئة والصحاري سوف تزداد بنسبة 4.5% و 0.75% على التوالي تقدم نتائج هذه الدراسة معلومات مفيدة عن خرائط ومناطق كوبن-جيجر المناخية المستقبلية التي من المرجح أن تتأثر في العقود المقبلة.

الكلمات المفتاحية: الكتلة الحيوية، المناطق المناخية، إدريسي أنديس البرمجيات، أسطح الأرض، الغطاء النباتي.