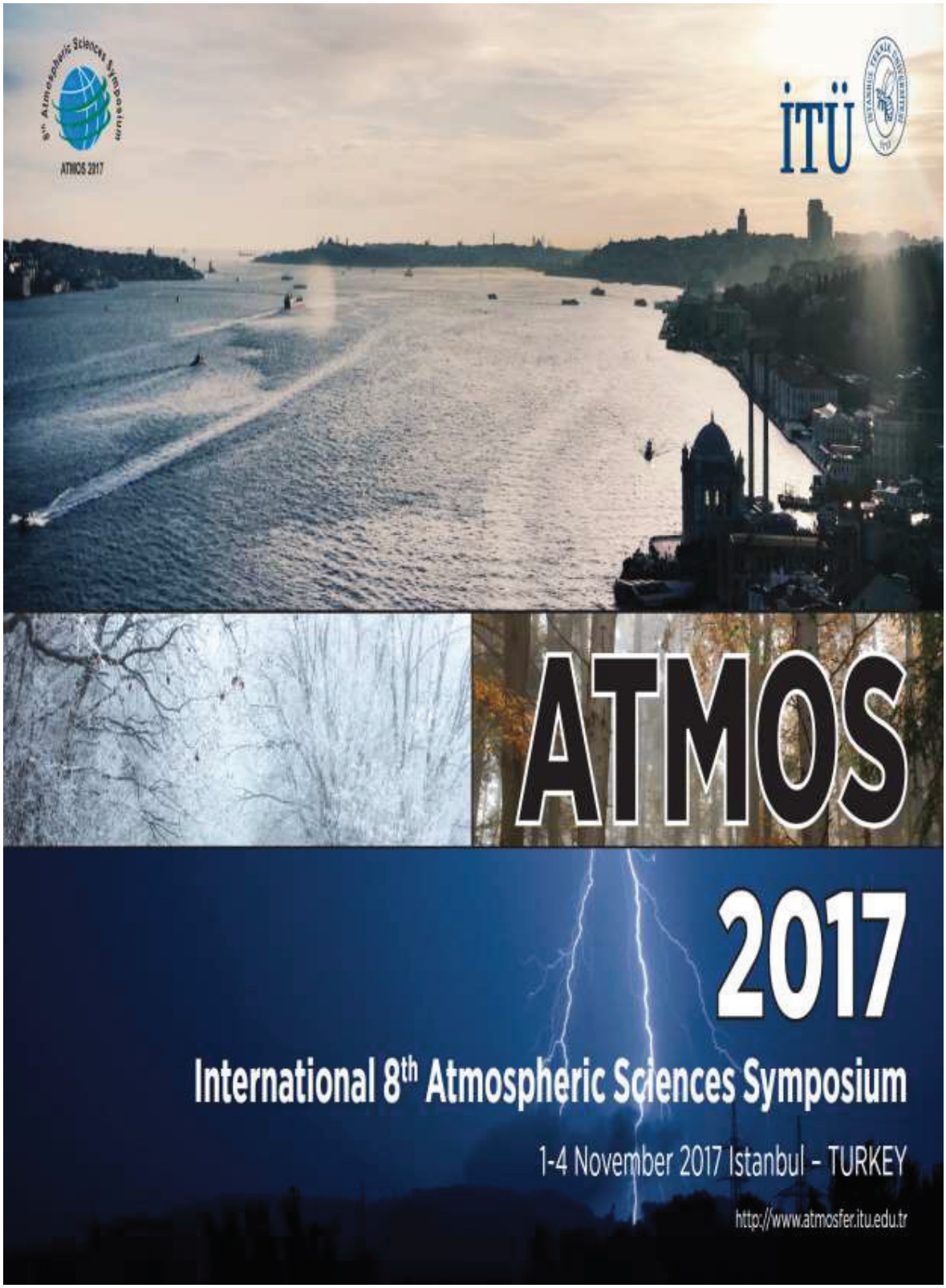
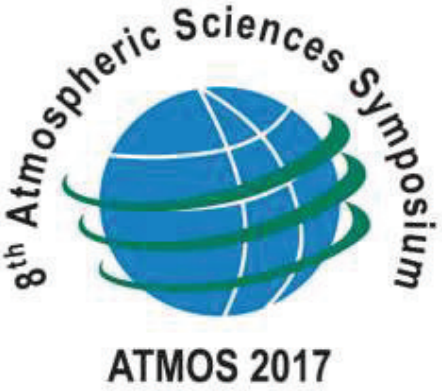

ATMOS
2017
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8th Atmospheric Sciences Symposium
ATMOS 2017

PREFACE

This 8th Atmospheric Sciences Symposium; ATMOS2017 built upon the series that began at Istanbul Technical University, Department of Meteorological Engineering in 1981. Subsequent meetings have been held in 1991; 2003; 2008; 2011; 2013 and 2015 in Istanbul, Turkey.

And it is not just enough to produce scientific data for people but it is also necessary to process the data and share the results of those data as a source for students and a starting point for all researchers, users and policy makers, it is a treasure for mankind.

We are very greatful and thankful to all the valuable researchers, session chairs and all participants who have contributed to ATMOS2017 from all around the world, whose valuable contributions made this event possible.

This e-Proceedings present a collection of 112 papers presented at the Symposium. The main themes covered in the Symposium include;

Agricultural and Forest Meteorology
Air Pollution and Modeling
Air Quality and Modeling
Air-Sea Interactions
Atmospheric Boundary Layer
Atmospheric Dynamics
Atmospheric Environment
Atmospheric Physics
Atmospheric Radiation
Aviation Meteorology
Biometeorology, Medical Meteorology
Causes of Climate Change
Chaos and Non-Linear Dynamics
Climate Change Impacts
Climate Change and Modeling
Climatology
Data Analysis
Extreme Weather Events (flood, storm, avalanche, drought …)
Hydrology and Hydrometeorology
Maritime Meteorology
Meteorological Disasters
Micrometeorology, Mesometeorology
Numerical Waether Prediction
Physics of Cloud and Precipitation
Remote Sensing in Atmospheric Sciences
Renewable Energy Sources
Solar and Wind Energy
Stratospheric Ozone
Solar and Climate System Interaction
Transportation Meteorology
Upper Atmosphere, Ionosphere
Magnetospheric Physics
Urbanisation Meteorology
Water Resources and Management
Weather Analysis, Prediction and Modeling

We would like to thank Rectorate of Istanbul Technical University and the Deanship of Faculty of Aeronautics and Astronautics for supporting ATMOS2017. We would like to express our appreciation to Organizing Committee Members, Steering Committee Members and Scientific Committee Members for their precious support. Last but not least we would like to thank Turkish State Meteorological Service, Union of Chambers of Turkish Engineers and Architects; Chamber of Meteorological Engineers for their valuable support.

Editors

Dr. Orhan ŞEN - Dr. Ceyhan KAHYA
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CLASSIFICATION OF THE KÖPPEN AND HOLDRIDGE LIFE ZONES WITH RESPECT TO THE CLIMATE SCENARIOS-RCP4.5 OVER TURKEY

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ABSTRACT

This study is suggesting a new perspective for monitoring the climate zones of Holdridge and Köppen by employing the 30-year moving average since 2006 to 2100 with respect to the climate scenarios. The aim of the both climate classification systems of Holdridge and Köppen is to group climatic quantities of temperature and precipitation at the local-scales according to some pre-defined restrictions such as vegetation index (cover). Holdridge uses bio-temperature, precipitation and evapotranspiration ratio; on the other hand, the long-term means of temperature and precipitation variables are used in the Köppen's system. The Holdridge system is mostly used to understand the possible biome (vegetation) characteristics. A computer program based on FORTRAN 2003 was developed for climate classification systems. In addition, the large-scale variables of the General Circulation Models (GCMs) used in the study were obtained from the 6 type ensemble simulations of the model entitled "ESM2M" of the Geophysical Fluid Dynamics Laboratory (GFDL) based on the scenario-RCP4.5 (Representative Concentration Pathways. RCP). The RCPs are the four-greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5). The results of the study show that the sub-classes from both classification systems of Köppen and Holdridge show that there will be noticeable changes in the northeastern parts of the country, and particularly in the southeastern parts of the country. According to the models, the south-eastern regions will have been almost completely faced with deep dry climate and/or desertification. In terms of water resources and management, it can be suggested that a new policy is needed to reduce the adaptation and mitigation of the climate change for Turkey.

***Key Words**: AR5, Climate Change, GFDL, Holdridge, Köppen, RCP4.5*

INTRODUCTION

In this study, the historical changes in vegetation cover in Turkey were quantified according to Köppen and Holdridge climate classifications based on climatic change scenario Representative Concentration Pathway (RCP) 4.5. It is a scenario of long-term, global emissions of greenhouse gases, short-lived species, and land-use-land-cover which stabilizes radiative forcing at 4.5 watts per meter squared (wm^{-2}), and approximately 650 ppm CO2-equivalent in the year 2100 without ever exceeding that value (Moss et al. 2010; Thomson *et al.* 2011). Climate change and its impacts could be brought together all the research fields contributing to a deep understanding of the ways in which we organize our lives with respective the new perspective.

A recent paper written by Chen and Chen (2013) looked at the change in spatial coverage of the major and minor Köppen categories across the entire earth as a metric for measuring climate change between 1900 and 2010. Köppen (Köppen, 1900) was trained as a plant physiologist and realized that plants are indicators for many climatic elements. His effective classification was constructed based on five vegetation groups determined by the French botanist De Candolle referring to the climate zones of the ancient Greeks (Sanderson, 1999). The five

vegetation groups of Köppen distinguish between plants of the equatorial zone (**A**), the arid zone (**B**), the warm temperate zone (**C**), the snow zone (**D**) and the polar zone (**E**). A second letter in the classification considers the precipitation (e.g. Df for snow and fully humid), a third letter the air temperature (*e.g.* Dfc for snow, fully humid with cool summer). Although various authors have published enhanced Köppen classifications or developed new classifications, the climate classification was originally developed by Köppen (here referred to as Köppen-Geiger classification) is still the most frequently used climate classification.

According to open literature, the Holdridge life zone (HLZ) system (Holdridge, 1967) can be regarded as the model considers some basic laws of plant physiology. For example, Lugo *et al.* (1999) have applied the HLZ to the conterminous United States. Chen *et al.* (2003) and Yue *et al.* (2015) have examined the possible responses of ecosystems to the climate change over China through the HLZ approach. Tatli and Dalfes (2016) have applied the HLZ to classify the vegetation zones associated with the surface climatic variables over Turkey. They have obtained fourteen types of the HLZ classes where the frequent zones are cool temperate steppe and warm temperate dry forests. On the other hand, the HLZ system was first suggested by Emanuel et al. (1985) to evaluate the effects of climate change on vegetation cover. Szelepcsényi et al. (2016) have applied HLZ by the temperature and precipitation values obtaining from 11 regional climate simulations to assess the possible ecological impacts of future climate change for the Carpathian region. In this study, the possible expected shifts in the spatial distribution of the HLZ types are investigated for Turkey, in accordance with the above-mentioned studies (Tatli and Dalfes, 2016).

DATA AND METHODOLOGY

Data

The global data set of climate simulations have been selected to update the historical world maps for both the Köppen-Geiger and Holdridge climate classes. The maps are generated from a large dataset of climate simulations by the data set obtained from the ensemble values of 6 "General Circulation Models" (GCMs) of so called "ESM2M (Dunne et al., 2012)" of the Geophysical Fluid Dynamics Laboratory for the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC).

The data set used in this study is obtained from the GCM based on the scenario of Representative Concentration Pathway (RCP) 4.5. It is a scenario of long-term, global emissions of greenhouse gases, short-lived species, and land-use-land-cover which stabilizes radiative forcing at 4.5 Watts per meter squared (w/m^2), approximately 650 ppm CO2-equivalent) in the year 2100 without ever exceeding that value. The RCP4.5 scenario in the set of experiments is described by Taylor *et a*l. (2012). These climate model data are freely accessible at the Program for Climate Model Diagnosis and Intercomparing website https://www.gfdl.noaa.gov/ipcc-ar5-data/.

Köppen-Geiger Climate Classification

According to the literature there are various versions of Köppen's climate classification have been faced. The calculation scheme for the Köppen-Geiger classes applied in this study will now be briefly described. The key points of this classification scheme are described in Table 1. The key to the main climates is characterized by the first two letters. The annual mean near-surface (2 m) temperature is denoted by *Tann* and the monthly mean temperatures of the warmest and coldest months by Tmax and Tmin, respectively. P*ann* is the accumulated annual precipitation and Pmin is the precipitation of the driest month.

Additionally, Psmin, Psmax, Pwmin and Pwmax are defined as the lowest and highest monthly precipitation values for the summer and winter half-years on the hemisphere considered. All temperatures are given in °C, monthly and annual precipitations in mm. In addition to these temperature and precipitation values a dryness threshold Pth in mm is introduced for the arid climates (B), which depends on "Tann", the absolute measure of the annual mean temperature in °C, and on the annual cycle of precipitation. Furthermore, the scheme how to determine the additional temperature conditions (third letter) for the arid climates (B) as well as for the warm temperate and snow climates (C) and (D), respectively, is given in Table 2, where Tmon denotes the mean monthly temperature in °C.

Table 1. The basics of the Köppen-Geiger Classification

Type	Description	Criterion
A	**Equatorial climates**	Tmin ≥ 18 °C
Af	Equatorial rainforest, fully humid	Pmin ≥ 60 mm
Am	Equatorial monsoon	Pann ≥ 25 (100 − Pmin)
As	Equatorial savannah with dry summer	Pmin < 60 mm in summer
Aw	Equatorial savannah with dry winter	Pmin < 60 mm in winter
B	**Arid climates**	Pann < 10 Pth
BS	Steppe climate	Pann > 5 Pth
BW	Desert climate	Pann ≤ 5 Pth
C	**Warm temperate climates**	−3 °C < Tmin < +18 °C
Cs	Warm temperate climate with dry summer	Psmin < Pwmin, Pwmax > 3 Psmin and Psmin < 40 mm
Cw	Warm temperate climate with dry winter	Pwmin < Psmin and Psmax > 10 Pwmin
Cf	Warm temperate climate, fully humid neither	Cs nor Cw
D	**Snow climates**	Tmin ≤ −3 °C
Ds	Snow climate with dry summer	Psmin < Pwmin, Pwmax > 3 Psmin and Psmin < 40 mm
Dw	Snow climate with dry winter	Pwmin < Psmin and Psmax > 10Pwmin
Df	Snow climate, fully humid neither	Ds nor Dw
E	**Polar climates**	Tmax < +10 °C
ET	Tundra climate	0 °C ≤ Tmax < +10 °C
EF	Frost climate	Tmax < 0 °C

Table 2. Key to calculate the third letter temperature classification (note that for type (b), warm summer, a threshold temperature value of +10 °C should occur for at least four months).

Type	Description	Criterion
h	Hot steppe / desert	Tann ≥ +18 °C
K	Cold steppe /desert	Tann < +18 °C
a	Hot summer	Tmax ≥ +22 °C
b	Warm summer	not (a) and at least 4 Tmon ≥ +10 °C
c	Cool summer and cold winter	not (b) and Tmin > −38 °C
d	Extremely continental	like (c) but Tmin ≤ −38 °C

Holdridge Life Zones

The Holdridge Life Zones (Holdridge, 1967) scheme is specified in Figure 1. In the HLZ algorithm, there are two hypothesizes: (i) The temperature and precipitation values are chief factors shaping life zones (or biomes). (ii) The vegetation is assumed to be independent of animals. The model practices three bioclimatic indices: mean annual bio-temperature (*BT*), total annual precipitation (*R*), potential evapotranspiration ratio *(PER*). It is central to know that the indices are depicted on logarithmic scale in the so-called life zone chart. As stated by the assumptions, the main influences on life zones are those aspects that structure climate of the Holdridge system. In this respect, it is not related the systems of Köppen (1931) and Thornthwaite (1948).

Holdridge (1967) defines BT as the temperature in the interval of [0 - 30ºC].

$$BT = \frac{1}{N}\left(\frac{1}{12}\sum_{i}^{12} T_i \quad \text{for } 0^{\circ}C < T_i < 30^{\circ}C\right) \tag{1}$$

where T_i is the temperature of *i-th* month and *N* indicates number of years, respectively. The *R* and *PER* values are obtained as in the following.

$$R = \frac{1}{N}\left(\sum_{i}^{12} P_i\right) \tag{2}$$

where P_i is the total precipitation of the *i*-th month.

$$PER = \frac{BT \cdot 58.93}{R} \tag{3}$$

After the values of *BT, R* and *PER* calculated, the HLZ classes can be determined by using the geometric model given in Figure 1.

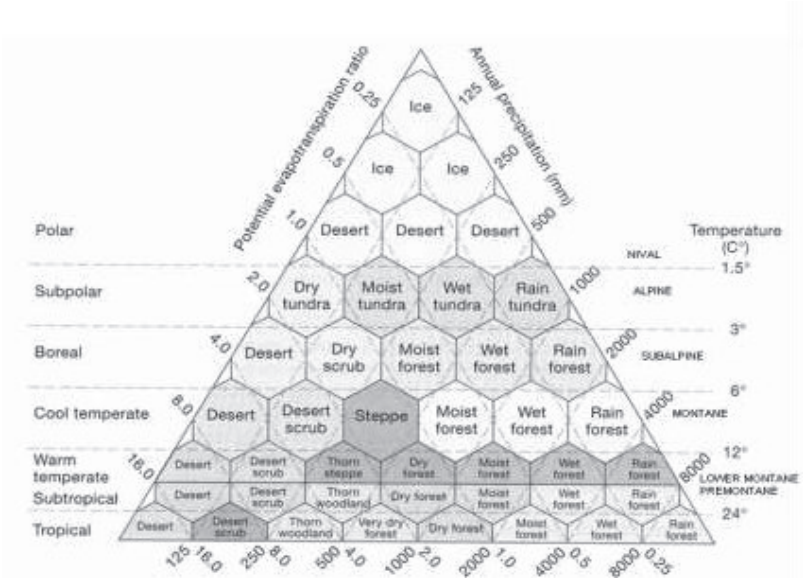


Figure 1 Holdridge's life zone system is one of most widespread for classification of climate-based vegetation types (after, Holdridge, 1967; Tatli and Dalfes, 2016).

RESULTS

Climatic classes were determined by taking 30-year moving-averages. That is, the averages are calculated for time intervals of moving windows such as 2000-2019, 2001-2030, ..., 2060-2089, 2061-2090, and so on. The map of the climate classes for 2006-2035 is shown in Figure 2. When this shape is closely diluted, a total of 5 sub-climate classes are observed over 2 basic Köppen climate of the "B nd C" types. As seen from this figure, there is a "C" type climate in

the Black Sea, Mediterranean, Aegean Sea borders and Central Anatolia region. On the other hand, "B" type climate is observed in the southeast part of the country and the westernmost part of the north-western part (including Çanakkale and Edremit Gulf).

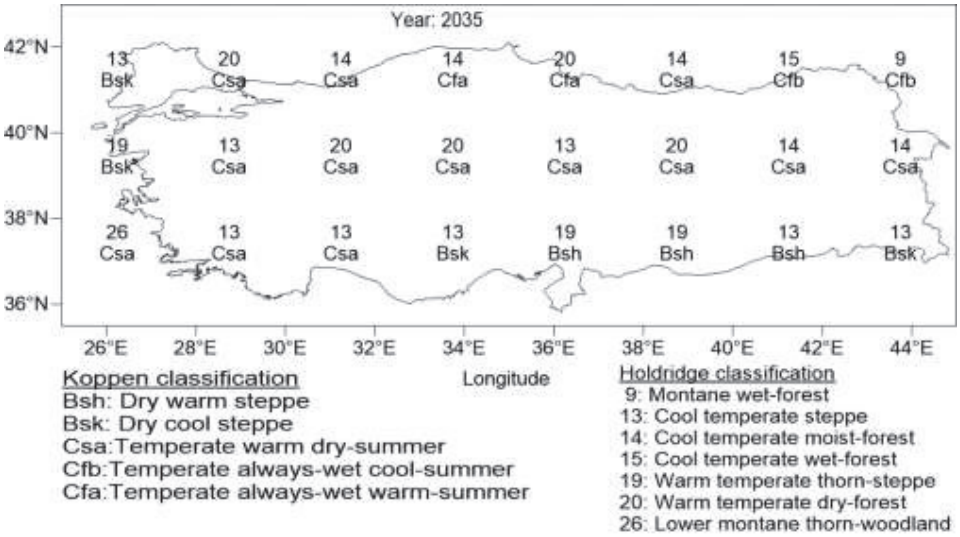


Figure 2. Distribution of the Köppen and Holdridge climate classes between the time interval of 2006 and 2035.

Similarly, when Holdridge climate classes are examined, it appears that there are 6 type climate classes in the country. As expected, the rainfall-forests in the Black Sea Region and more steppe species in the inner region are noteworthy. “Cool temperature” sub-climates are seen due to the grids located in the south of the country, and in the continental section of the Toros Mountains range. The reason for the lack of the marine effect is that the geographical coordinates of the model grids do not fall on to the shore. Southeastern Anatolia, as expected, has a climatic steppe that dominates the temperature. On the Çukurova region, where the effect of the mountains is partially diminished, war-temperate thorn-steppe climatic classes are seen.

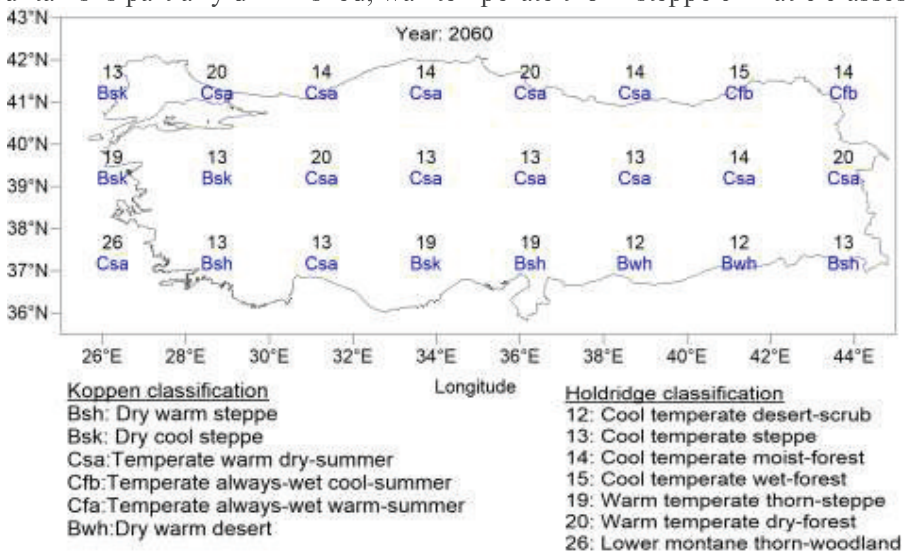


Figure 3. Distribution of the Köppen and Holdridge climate classes between the time interval of 2036 and 2060.

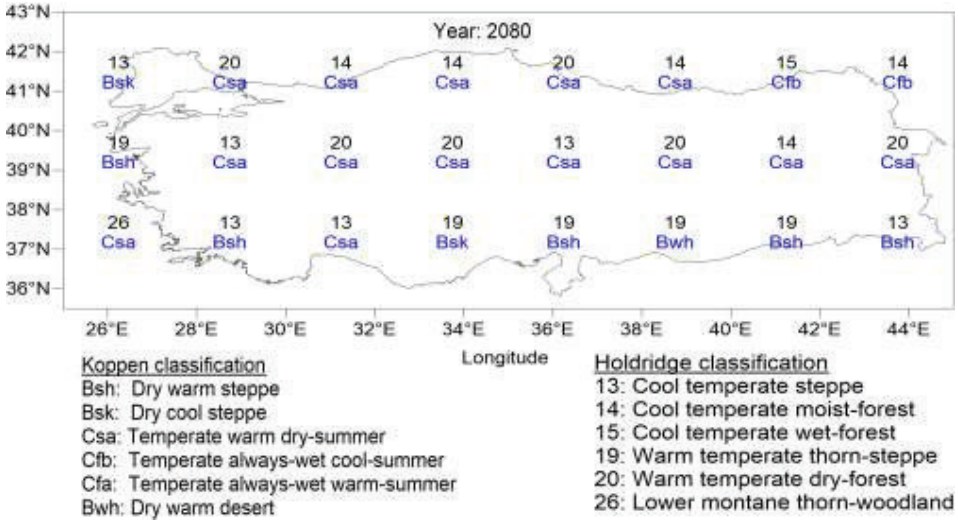


Figure 4. Distribution of the Köppen and Holdridge climate classes between the time interval of 2061 and 2080.

Correspondingly, from Figures 3 to 5, the distribution of Köppen climate types over the country mostly show that Subtropical Summer (Cs) will be deepen, turning into warm and dry summer. Those turning will lead to decrease crop yield. The Dry Semi-Arid (Bs) and Subtropical Summer-Dry (Cs) over the coastal regions. The Cs type, except southeastern and northwestern parts of the country dominates entire areas as well, while the always -wet cool summer (Csb) will be seen only in the eastern Black Sea basin.

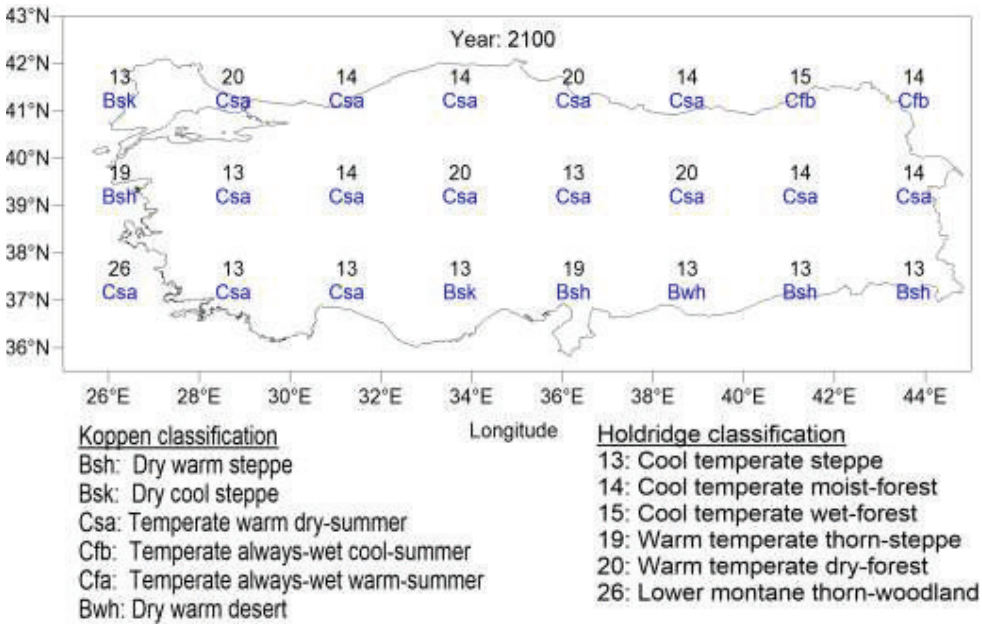


Figure 5. Distribution of the Köppen and Holdridge climate classes between the time interval of 2081 and 2100.

According to the distribution of HLZ classes as seen from Figure 3 to 5, there will be a shift towards dry and hot steppes, particularly in the southeastern part of the country. The RCP 4.5 scenario is an optimistic mode that corresponds to the old synchronized B1 middle level

optimistic scenario. Therefore, there will be little change in both Köppen and HLZ climate classes is expected.

CONCLUSIONS

In this study, the sub climate classes of Köppen and Holdridge types in Turkey were analyzed by generated from the ensemble values of GCMs of so called "ESM2M (Dunne et al., 2012)" of the Geophysical Fluid Dynamics Laboratory for AR5. The investigation focused on the large-scale spatial distribution of 30-year moving windows from the date of 2005 to 2100. The RCP4.5 scenario is a mid-level optimistic scenario. In other words, large-difference climates in the country were not achieved because the world countries were supposed to assume their duties on climate change. A pathway for "stabilization of radiative forcing" by 2100. In that case, since the climate change cannot be completely prevented for decision-makers, it can be suggested that the best scenario for Turkey (the good of the evil) is the RCP4.5. In this case, studies can be done based on this scenario in the country's climate change and damage prevention and international policies.

For future studies, determining changes in biomes under consideration of the climate scenarios in Turkey will be useful, and the biomes-changes could be verified with historical observations and data from remote sensing imagery.

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