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RESEARCH ARTICLE

FUTURE PROJECTION OF OLIVE PRODUCTION IN ÇANAKKALE

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ABSTRACT

Global warming is one of the most important problems in the world due to its effects not only on human life but also on agricultural products and food safety, sustainability, and water resources. The present study aims to investigate the influence of climatic changes on olive cultivation in North-West Turkey for the next 50 years. In this context, the data were collected from 182 coordinates in olive cultivation areas in Çanakkale which is situated at the intersection of the Euro-Asian region. The data were analysed using MaxEnt software to determine the projection of olive cultivation for the next 50 years. The results show that the optimistic scenario is (representative concentration pathways) RCP 2.6 (2070) while the pessimistic scenario is RCP 8.5 (2070) for Çanakkale olive cultivation. When the results were compared with the current conditions of Çanakkale, the RCP 2.6 scenario indicated that potential olive cultivation areas would mostly be protected. On the other hand, according to the worst scenario, these areas would decrease in size. All of the scenarios, however, show that olive cultivation areas will spread towards the mountainous areas of Çanakkale. Additionally, total olive cultivation areas in Çanakkale will increase depending on climatic changes in 2070. In conclusion, even if climatic changes may lead to an increase olive production yield, their effects on olive and olive oil quality are unknown.

Keywords: *Climate change, Scenario analysis, Risk, Adaptation, Yield, Olive cultivation*

1. INTRODUCTION

Global climate change is one of the most important problematic issues of the 21st century. The effects of global climate change increase due to the increasing world population, technological advances, and changes in industrial conditions and human-based conditions [1,2]. According to the fifth report of the Intergovernmental Panel on Climate Change (IPCC), land and ocean temperature data show an increase of 0.9 °C between 1901 and 2012. Atmospheric concentrations of CO_2, CH_4, and N_2O gases have increased more than ever in the last 800,000 years [3]. CO_2 concentration increased by 40% compared to the pre-industrial period. The main reason for this situation is the use of fossil fuels and the second reason is the change in land use. According to this report, 4 Representative Concentration Pathways (RCP) have been identified for climate change scenarios. It has been predicted that CO_2 concentration by 2100 would be 1370 ppm for RCP 8.5, 850 ppm for RCP 6.0, 650 ppm for RCP 4.5 and 490 ppm for RCP 2.6. By these scenarios, temperatures (1.5-5.8°C) increase and precipitation is expected to decrease. Among these scenarios, RCP 2.6 is the scenario where the effects of climate change will be least seen [4]. The IPCC, currently in its 6th phase, published its 1.5 ºC Report on Global Warming in October 2018 and emphasized that 1.5 °C warming would be relatively safe compared to 2 °C in terms of potential climatic effects. If the temperature rise cannot be limited to 1.5 °C, in other words, if CO_2 concentration (490 ppm) is exceeded in the RCP 2.6 scenario, the effects of climate change may have more devastating consequences [5]. As a result of this, forests and flora, drinkable water sources, and agriculture are directly or indirectly affected along with sea level, energy sources, human health and biodiversity [6]. Particularly, many researches have indicated that agriculture, livestock, fisheries and food will be most affected by global climatic changes [7]. Besides, agricultural production leads to climatic changes in itself due to greenhouse gases such as CO_2, CH_4, and N_2O. Climatic changes result in a potential change in rainfall, which reduces irrigation water and efficient agricultural areas and leads to desertification or relocation. Therefore, food safety is negatively affected as a consequence of the increasing climatic stress on agricultural production. This situation makes it harder to reach drinkable water, safer food, and healthier nutrition as well as leading to social and economic problems [8,9,10].

Moreover, local foods and patented foods or products will be negatively affected or will perish [11-19]. According to one theory, *Olea chrysophylla* and *Oleaster Olea sylvestris*, which are the ancestors of the olive tree (*Olea europea*), were cultivated in the big area of the Sahra before the Pleistocene epoch. The first cultivation of the olive tree was made thousands of years ago in Egypt; however, it perished because of an unknown reason in 2000 B.C. [20,21]. The olive tree is one of the most ancient cultivars in the world. Olive and olive oil, which are the products of the olive tree, are found in legends, ancient civilizations inscriptions and holy books [20,21]. In the literature, data indicated that olive had been cultivated even 6000 years ago [20]. It is generally agreed that olive originates in South East Anatolia, Mesopotamia and East Asia [20]. The olive tree cultivation is done between 30-450 latitude in the world where winters are soft and rainy, summers are dry, and springs are partly cold and rainy [21]. In literature, were reported that the climatic conditions of the olive tree were 16-21 °C of annual temperature, 500-1200 mm amount of total rain, 5000 h insolation time and enough chilling time [21]. According to the 2018 data, the amount of the world production of olive and olive oil was 21 million tons and 3.1 million tons in 10.5 million ha areas, respectively [22]. According to the 2019 data, there were 182 million trees in Turkey, while the amount of olive and olive oil production was 415,000 tons (table olives), 1.1 million tons (for oil) and 263,000 tons in 864,428 ha areas, respectively [23]. Moreover, there were 5.3 million trees in Çanakkale, the amount of olive and olive oil production in Çanakkale was 11,000 tons (table olives), 85,000 tons (for oil) and 16,995 tons olive oil in 325,731 da areas, respectively [23].

In order to predict how species would be distributed in climate change, it is necessary to determine the climatic conditions of those areas in which species are currently distributed. Afterwards, it is necessary to estimate in which areas the determined climatic conditions will continue or will not be continue. To make these estimations, we entered the analysis process through Maximum Entropy (MaxEnt) method. MaxEnt can predict the climatically suitable habitats of species in the present and future by means of bioclimatic data (bio1 - bio19) and the data of the target species [24-26].

As mentioned above, olive and olive oil are one of the most important products of the human diet not only in Çanakkale province and Turkey but also in the world. This study aimed to investigate the potential effects of global climate change on olive and olive oil production in Çanakkale province.

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2. EXPERIMENTAL DESIGN AND EVALUATION

2.1. Study Area and Species Data

Çanakkale province is located between longitudes 25° 35’ and 27° 45’ E and between latitudes 39° 30’ and 40° 45’ N (Fig.1). The average temperature of Çanakkale between 1970 and 2011 was 15 °C and had an increasing trend. The maximum daily temperature measured from 1970 to 2011 was 39 °C (23.07.2007), and the minimum daily temperature was -11.8 °C (14.02.2004). July is the hottest month with an average temperature of 24.6 °C, while January is the coldest month with an average temperature of 6.2 °C. The average rainfall and the difference in precipitation between the driest month and the wettest month were 637 and 104 mm, respectively [27]. One hundred and eighty-two coordinate data were collected from olive groves in Çanakkale where at least 40 trees were found. The data were obtained from the areas where both natural and planted olive trees were located. These olive trees are mostly belong to the domestic Ayvalık cultivar in Turkey Aegean seaside according to Öğütcü et al. (2008).

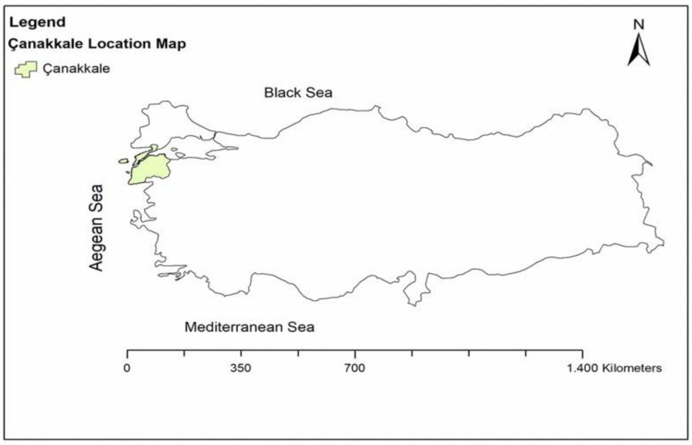

Figure 1. Location map of Çanakkale province, Turkey.

2.2. Bioclimatic Data and Habitat Suitability Model

Nineteen bioclimatic data were downloaded from http://www.worldclim.org [28]. In Version 1.4, HadGEM2-ES-based 19 bioclimatic data (Table 1) were downloaded on a global scale, with current (1950-2000) and future (2070) climate projections (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 scenario). Then, these data were processed at Çanakkale scale by using ArcGIS 10.2 software and made ready for analysis. At the end of all these processes, current and future bioclimatic data with a cell size of 874 x 874 m^2 (30 arc seconds) and a latitude/longitude coordinate WGS84 were obtained in "ascii" format.

MaxEnt software is an ecological niche modelling algorithm for estimating the probability of distributions based on the principle of maximum entropy [29]. The analysis was conducted using MaxEnt software v.3.4.1. MaxEnt use only presence data of species to determine environmental factors that make up the habitat of a species and to estimate its potential distribution. MaxEnt makes

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the best estimation and the best results with the least data and the smallest areas compared to other modelling methods [24].

The Olive presence data (csv.), the bioclimatic data (ascii) and the future climate projection data (ascii) were entered under "samples," "Environmental Layers" and "Projection layers directory/file", respectively. In the settings section, the training data were set to be 90%, the test data were 10%, and the number of iterations was 10, and the analysis started [29,30]. The MaxEnt model results were evaluated in two ways. The first way was the receiver operating characteristic (ROC) curve and area under the curve (AUC). The other way was the Jackknife test which showed the contribution of each independent variable used in the model [31,32]. If the climatic variable were not contributing to the model, this variable was removed in the Jackknife test result. This analysis procedure would help determine the current climatic conditions which were essential for the survival of olives and allow us to predict where these conditions would end and continue in the future.

Table 1. Bioclimatic variables used for future projection of olive cultivation.

Code	Bioclimatic Variables	Unit
Bio1*	Annual Mean Temperature	ºC
Bio2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	ºC
Bio3	Isothermality (Bio2/Bio7)* 100)	-
Bio4	Temperature Seasonality (standard deviation *100)	C of V
Bio5	Max Temperature of Warmest Month	ºC
Bio6	Min Temperature of Coldest Month	ºC
Bio7	Temperature Annual Range (Bio5-Bio6)	ºC
Bio8	Mean Temperature of Wettest Quarter	ºC
Bio9	Mean Temperature of Driest Quarter	ºC
Bio10	Mean Temperature of Warmest Quarter	ºC
Bio11	Mean Temperature of Coldest Quarter	ºC
Bio12	Annual Precipitation	mm
Bio13	Precipitation of Wettest Month	mm
Bio14	Precipitation of Driest Month	mm
Bio15	Precipitation Seasonality (Coefficient of Variation)	C of V
Bio16	Precipitation of Wettest Quarter	mm
Bio17	Precipitation of Driest Quarter	mm
Bio18	Precipitation of Warmest Quarter	mm
Bio19	Precipitation of Coldest Quarter	mm

*The highlighted variables were contributed in modeling.

3. RESULT AND DISCUSSION

Figure 2 shows the area under the ROC curve, or simply the AUC values of the training and test data. According to Fig. 2, AUC values of the training data and test data were 0.994 and 0.994, respectively. These results demonstrated that bioclimatic factors were affecting the distribution of olives (*Oleo europea L.*), especially Bio 1 (mean value of temperature per year). The other effective factors on the olive cultivation were Bio 11 (mean temperature of the coldest quarter), Bio 12 (Annual precipitation) and Bio 17 (average three arid months of precipitation) (Fig. 3).

Figure 2. Receiver operating characteristics curve or simply area under the curve values of the training and test data.

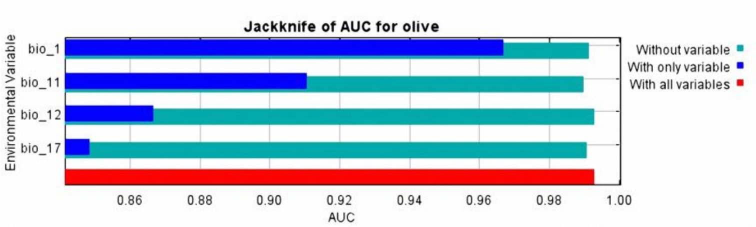

Figure 3. Bio-climatic factors affecting the distribution of olive cultivation.

In the present day, olive cultivation demands habitats that have 15 °C as a mean value of temperature per year, 7 °C as an average temperature of the coldest three months, 600-700 mm for annual precipitation and 40 mm for average three arid months of precipitation (Fig. 4). Similar to our findings, Crisci et al. [33] reported that climatic changes were commonly dependent on an increase in minimum temperatures rather than on changes in maximum temperatures.

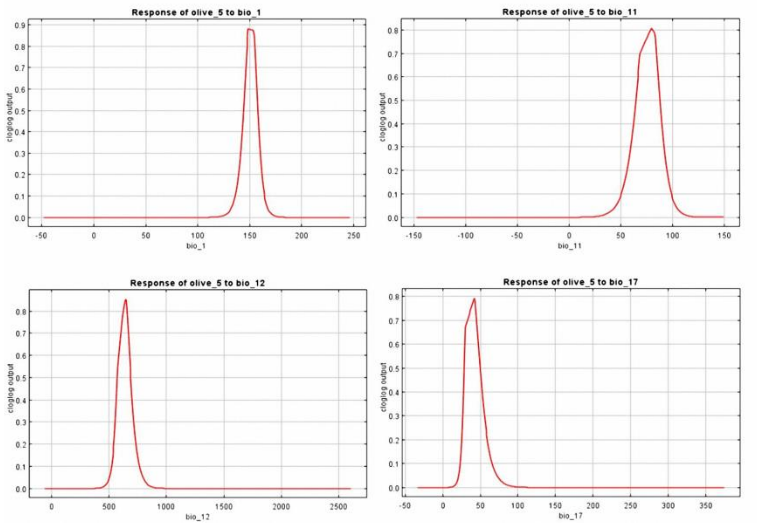

Figure 4. Factors affecting olive cultivation habitats in the present day.

According to bioclimatic changes, the olive cultivation suitable map of Çanakkale are given in Figure 5. Çanakkale is among the important olive producer provinces of Turkey in terms of olive production potential. Considering the conditions mentioned above, olive cultivation were mainly observed in the Aegean Sea side of Çanakkale as well as Bozcaada and Gökçeada islands (Fig. 5a). In the 2011 data reported, the olive production values of Çanakkale were 128.896.200 TL. Olive was substantially cultivated in the districts of Ezine, and Ayvacık in Çanakkale [34]. These results proved that olive cultivation was important in terms of agricultural economic input in Çanakkale. Orlandi et al. [35] and Galán et al. [36] demonstrated that there was a close relationship between climate and reproductive phenology in olive. In the same study, researchers indicated that olive flowering could be considered a good indicator of climate change [35,36].

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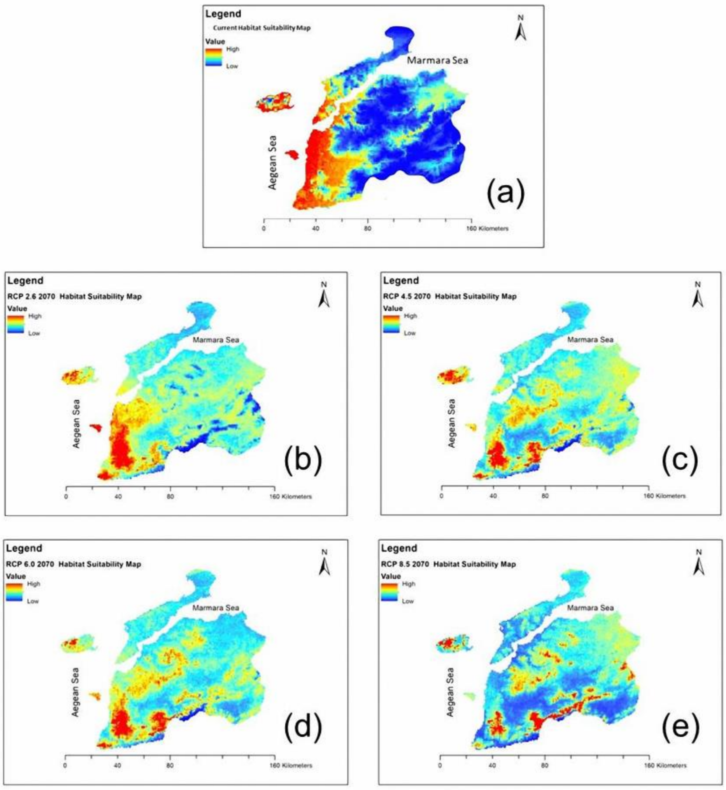

Figure 5. The suitable olive cultivation map of Çanakkale, (a) current distributions, (b) RCP 2.6 (2070) scenario, (c) RCP 4.5 (2070) scenario (d) RCP 6.0 (2070) scenario (e) RCP 8.5 (2070) scenario.

The RCP 2.6 2070 scenario is shown in Figure 5b. According to this scenario, olive cultivation will mainly protect its cultivation areas, alongside it will be spread on the inland of Çanakkale which areas are currently mountainy. In this aspect, the scenario RCP 2.6 2070 is the better scenario among the other climatic changes scenarios for olive cultivation of Çanakkale. When today's conditions and RCP 2.6 results compared, it is seen that olive cultivation will reduce in Gökçeada and especially Eceabat districts. Indeed, the RCP 2.6 scenario is closely similar to the ICCP 1.5 °C report. RCP 4.5 2070 scenario shows that olive cultivation will not be suitable for the coastal areas near the seaside of Çanakkale (Fig. 5c). Additionally, olive cultivation will decrease in Bozcaada district, while it will be distributed to north-east Çanakkale. Similar results were observed RCP 6.0 2070 scenario (Fig 5d). The worst scenario is RCP 8.5 2070 in terms of Çanakkale olive cultivation. In this scenario, it is expected that the olive production will decrease due to the estimated reduction in the areas that are currently suitable for olive cultivation (Fig. 5e). According to these results, if especially the RCP 8.5 scenario happens, the olive farmers and olive oil producers of Çanakkale will be economically be damaged. It has been observed that new potential areas have emerged despite the reduction of existing olive growing areas for all scenarios. On the other hand, the most convenient olive cultivation areas compared to current conditions will decrease according to the 2070 RCP scenarios. Even if these results may lead to an increase in olive production yield, the effects on olive and olive oil costs, yield and quality are unknown. Tanasijevic et al. [37] reported that olive cultivation areas extending to the North and to higher altitudes would increase by 25% in 50 years. Gutierrez et al. [38] reported that olive cultivation would spread to unfavourable cold areas in higher elevations in the Apennine mountains in central Italy and in the Po Valley in the north. Moreover, climate change is expected to contract the range of olive cultivation in southern desert areas and to spread it northward and alongside coastal areas in CA-AZ [38]. The fact that climate warming would affect olive yield and result in economic winners and losers at the local and regional scales in the Mediterranean were reported by Ponti et al. [39]. In the same study, researchers predicted that profitability of small olive farms in many marginal areas of Europe would decrease at the local scale [39]. Literature findings are close similar to our results.

4. CONCLUSION

Even the pessimistic scenarios estimated that the olive cultivation of Çanakkale would continue and that it may not, however, be economically sustainable due to its spreading over rugged and high areas. Supply and demand balance of olive and olive oil cultivation will change in the future and olive and olive oil prices will, therefore, be higher than those of the current economic status. Indeed, olive and olive oil will be the most precious food products in the future scenarios. It is demonstrated that climatic changes affect agricultural products that are the raw material of food products. It is well known that the world population increases while the food and water resources of the world decrease day by day. In this aspect, the protection of agricultural products and food safety will be very important in the future.

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