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IMPACT OF CLIMATE CHANGE ON TEA YIELD: AN ANALYSIS FOR THE BLACK SEA REGION*

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Abstract

Climate change directly affects Turkey's agricultural output and yield. Tea is among the products that are expected to be affected by climate change. Changes in the tea yield, which is an important socio-economic function, are expected to have negative consequences. This effect was examined retrospectively for the period 1970-2018 using the panel data method. According to the empirical analysis results, it has been revealed that the temperature increase has a positive effect on tea yield up to a certain threshold value. On the other hand, it has been observed that the irregularities in the precipitation regime have a decreasing effect on the yield. In contrast, the decrease in frost events in parallel with the warming increases the yield. It is expected that the precipitation will become irregular in future scenarios, and the temperature differences will increase. Considering these scenarios, it is predicted that tea production and yield will decrease, leading to negative consequences such as labor force participation, migration and economic losses.

Keywords: Climate Change, Tea Yield, Agricultural Output

JEL Classification: Q5, Q54, Q18, R11

İKLİM DEĞİŞİKLİĞİNİN ÇAY VERİMİ ÜZERİNDEKİ ETKİSİ: KARADENİZ BÖLGESİ İÇİN BİR ANALİZ

Özet

İklim değişikliği, Türkiye'nin tarımsal çıktı miktarı ve verimini doğrudan etkilemektedir. Çay, iklim değişikliğinden etkilenmesi beklenen ürünlerin arasında yer almaktadır. Önemli bir sosyo ekonomik fonksiyonu olan çayın verimindeki değişiklerinin olumsuz sonuçlar doğurması beklenmektedir. Bu etki geçmişe yönelik olarak 1970-2018 dönemi için panel data yöntemi kullanılarak incelenmiştir. Ampirik analiz sonuçlarına göre sıcaklık artışının belirli bir eşik değere kadar çay verimi üzerinde pozitif etkiye sahip olduğu ortaya konulmuştur. Öte yandan yağış rejimindeki düzensizlikler verimi azaltıcı, ısınmaya paralel olarak don olaylarındaki azalışın verimi arttırıcı yönde etki ettiği gözlemlenmiştir. Gelecek senaryoları kapsamında yağışların düzensizleşeceği ve sıcaklık farklarının artması beklenmektedir. Bu senaryolar göz önüne alındığında çay üretimi ve veriminin azalacağı, bu durumun ekonomik kayıpların yanısıra, işgücüne katılım ve göç gibi negatif sonuçlara yol açabileceği öngörülmektedir.

Anahtar Kelimeler: İklim Değişikliği, Çay Verimi, Tarımsal Üretim

JEL Sınıflandırması: Q5, Q54, Q18, R11

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1. Introduction

While the effects of climate change (CC) on agricultural output were a narrative for many people a decade ago, it has become a reality that we frequently encounter today, affecting our lives. Climate belts have shifted from equatorial regions to upper parallels. The Mediterranean basin, in which Turkey is located, is one of the regions most affected by climate change. In addition to precipitation and temperature anomalies, the danger of drought awaits Turkey's region. The 1.5-degree warming target set by the Intergovernmental Panel of Climate Change (IPCC) has been already reached (IPCC, 2018). Tea is one of the products that will be affected by the effects of CC on agricultural output and it is the most consumed beverage globally out of the water as 6.3 billion kilograms of tea was consumed in 2020 (İstikbal, 2020). Tea production in Asian countries such as China, Sri Lanka, and India, where the equatorial climate is dominant, has spread throughout the year (Rize Commodity Exchange Market, 2021). In Turkey, tea cultivation is carried out for six months between April and September due to the microclimate characteristics of the Eastern Black Sea region and that characteristic increases the tea quality.

Tea has a significant economic value for many geographies besides its social function. The global tea market had an approximately 200 billion dollars value in 2020, and this is predicted to be 318 billion dollars in 2025 (Statista, 2021). In Turkey, which ranks high in the world in per capita tea consumption, the importance given to tea is relatively high in economic and social terms. Tea, which has a place in our lives as an essential beverage, is grown in a limited geography, but its specific gravity is beyond the geography produced. Tea cultivation in Turkey is carried out in the Eastern Black Sea region from the Georgian border to the Fatsa district of Ordu and the tea industry provides permanent or seasonal employment of approximately a million people when its back and forth connections are considered (FAO Intergovernmental Group on Tea, 2018). With a total of 207 active factories, it is of vital importance for the economic activity of the Eastern Black Sea region (Rize Commodity Exchange Market, 2021). The Eastern Black Sea Region allows efficient production of a limited number of products due to its rough terrain, climate, and soil conditions, and the leading one is tea. Although Turkey has 4% and 2% shares in world tea production and planted area respectively, its national importance is relatively high (FAOSTAT, 2018). As shown in Table 1 (share in the given province), the shares of tea agriculture in total agricultural activity are 99%, 70%, and 49%, especially in Rize, Artvin.

On the other hand, the same table clearly shows in which provinces tea production is made. While Rize has 65% of the national tea cultivation areas, Trabzon and Artvin are around 20% and 11%, respectively. Calculations are in terms of the total cultivated area, not the production amount. The proportions of tea cultivation areas in the national total have not changed significantly over time. The change in how important tea has become in the provinces where it is produced can also be seen in table 1.

Table 1: Tea Production Shares at Provincial and National Scale (%)

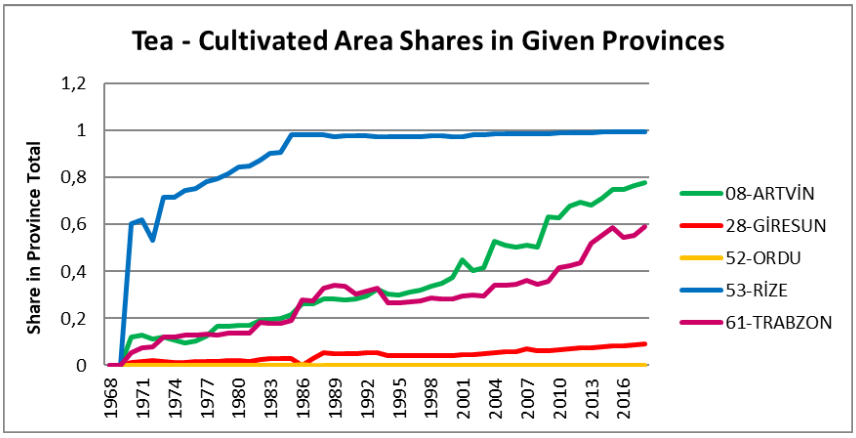
	Cultivated Tea Area Share in Given Province					Province's Share in National Total				
	68 - 78	*78 - 88*	*88 - 98*	*98 - 08*	*08 - 18*	*68 - 78*	*78 - 88*	*88 - 98*	*98 - 08*	*08 - 18*
Rize	56,9	91,2	97,5	98,2	99,1	66,5	65,9	63,9	65,3	65,9
Trabzon	8,77	20,3	29,9	31,9	49,9	19,1	21,3	21,8	20,6	20,3
Artvin	9,84	21,2	30,4	45,6	70,6	11,1	10,4	10,9	11,2	11,2
Giresun	1,29	2,51	4,67	5,31	7,82	2,97	2,27	3,17	2,86	2,60
Total	N/A	N/A	N/A	N/A	N/A	**99,9**	**99,9**	**99,9**	**99,9**	**99,9**

Note: Shares were calculated in terms of cultivated area. They are the author's own calculations by using TURKSTAT statistics.

It is estimated that tea, which had a revenue of 2.7 billion dollars in the Turkish economy as of 2018 as a sector, will reach a 4 billion dollars market size in 2025. Depending on the increase in tea consumption, it is foreseen by FAO that tea production will increase from 270 thousand tons to 400 thousand tons in 2031. Especially in the economic life of Rize and Artvin, tea production and, therefore, the tea sector is in an unrivaled position.

Tea producers have faced various economic problems in recent years. Foremost are market disruptions and input costs caused by quotas. However, much greater perils await tea producers in the medium and long term, entitled climate change. Both the studies of the FAO Intergovernmental Group on Tea (IGG on Tea, 2018) and other scientific researches show the climate crisis, which causes changes in the temperature and precipitation patterns, is manifested by the increase in the frequency of events such as floods and droughts. This fact has begun to impact tea yield as well as on product quality and prices. Therefore, it would not be pretentious to say that climate change will be the most crucial factor threatening tea production in the medium and long term. According to the same report, it is estimated that the areas where tea is grown may decrease by 50% in 2050 (IGG on Tea, 2018). One of the most prominent examples of the foreseen concrete effects is the effects of the extreme heatwave encountered on a global scale in 2013 on tea which caused to reduce production and yield. Furthermore, increased frequency of floods and landslides during the last decade in the Black Sea region complicates tea cultivation on rough terrain, and harvesting cannot be performed in some areas.

Figure 1: Cultivated Tea Area Shares in Given Provinces



Source: Author's own calculations by using TURKSTAT statistics

2. Literature

There are not many studies on tea in Turkey. The most comprehensive analysis of the effects of CC on tea is FAO's Intergovernmental Group on Tea work. In this study, it is mentioned that the problems related to supply will be marked by climate-related restrictions in the near future (IGG on Tea, 2018). One of the reasons behind this is that the private and limited areas where tea grows are the regions that have the potential to be most affected by CC. Another study by Scott et al. (2020) revealed that excessive precipitation and high temperatures could increase tea production but cause significant decreases in tea quality. The report (FAO, 2015a) underlined that temperatures are as effective as precipitation on the tea yield of Kenya, one of the leading global tea producers and that extreme temperatures limit drought and humidity and reduce yield. Another field study carried out by FAO emphasized that tea farms in China would shrink due to climate change, agro-meteorological and ecological disasters would be recorded, and the tea industry would face significant dangers (FAO and CAAS, 2021).

Climate data collected by KALRO Tea Research Institute (TRI) for 58 years in East Asia and Africa indicates a temperature rise of 0.016°C per year while annual rainfall decreased by 4.82 mm per year over the same period (Cheserek et al., 2015). This will cause severe water deficiency in the soil. According to the model developed by Bore and Nyabundi (2016) for Kenya, it is estimated that the tea grown area will decrease by 22% in 2075. In another study, the results of the models revealed that the shrinkage of the total cultivated area and the adverse effects on the yield would create an upward pressure of 26.3% on the prices in Sri Lanka and India, the two largest producers today (FAO, 2015b). However, CC adaptation and mitigation costs require significant investments. Considering that a significant part of tea producers are smallholders in producer countries such as India, Sri Lanka, Kenya, China and Turkey, this will create substantial cost pressures on producers. This situation poses a danger to millions of small producers living at the poverty line, although their numbers cannot be determined precisely.

Most of the studies on tea production and yield in Turkey have been carried out on a micro-scale within the agricultural faculties. They are mostly consist of plant-specific phenological studies. Unfortunately, the number of studies on a macro level and economic perspective is very limited. In his study examining the micro effects of climate change on tea, Bütüner (2019) predicted that climate change might cause changes in tea's growing and harvesting seasons.

One of the studies for Turkey having contemplate the subject from a different point of view was carried out within the scope of the project of "Improving Women's Labor Force Awareness in the Agricultural Sector in Turkey in a Changing Climate (Bogaizi University and Rize Municipality, 2018)". Results stated that precipitation and temperature anomalies in the region would lead to the deterioration of the land structure in the tea-planted areas, reducing the labor force participation rate of women. Considering that Rize is the second province with the highest female labor force participation in agriculture, it has enormous potential in a negative way. Zeydan and Lise (2020) emphasized that the pests that will arise due to climate change will have devastating effects on tea yield. In Turkey, in parallel with the world, tea production is carried out by small producers. 74% of the total producers in Turkey produce in an area of 0 - 5 decares (Önçırak, 2019). Small-scale producers are expected to be more affected by climate change. Therefore, it is critical to increase mitigation and adaptation capacities. For this reason, there is a need for retrospective and prospective empirical studies that will examine the relationship between climate change and tea in economic terms for Turkey.

3. Data Source and Processing

It has been analyzed the effect of climate change on tea yield by using panel data method for the years 1970 - 2018. The works in this section consist of collecting and organizing the data that will form the basis of the analysis part of the study and, therefore the conclusion part. A list of variables and their details have given in table 2. The collected data can be analyzed in three parts as of first is climate data.

It was benefited from the database published by the CRU (Climatic Research Unit, 2019). Raw data on a monthly basis between 1960-2018 were processed by masking and interpolation method using different statistical programs including R etc. and has been made available for processing on a provincial basis. It has used a global high-resolution (0.5 degrees) gridded data set from the Climatic Research Unit (CRU) of the University of East Anglia for climatology data. The CRU monthly time series (CRU TS version 4.03) covers the period between 1901 and 2017 for several climate variables such as precipitation, temperature (mean, maximum, minimum, and diurnal range), wet day frequency, vapor pressure, cloud cover, frost day frequency and potential evapotranspiration (Harris et al., 2014). CRU data (2019) were downloaded for only maximum, minimum, and mean temperatures, precipitation, frost day frequency, and potential evapotranspiration. Since this is a global data set in netCDF files, we need to preprocess the raw data to prepare the time series for each city for the 1970 - 2018 time period. The netCDF file format is commonly used in the climate community (Unidata, 20) and employed several software and programs too including R, Climate Data Operator (CDO), and NCL script (NCAR Common Language, 2019) to process the raw CRU data.

Table 2: Data Types and Sources

Variable	Category	Source	Time Range and Frequency
• Mean temperature, • Maximum temperature • Minimum temperature • Total precipitation • Potential evapotranspiration • Frost day frequency	Climate	CRU TS (East Anlia University Climatic Research Unit) (1967 – 2018)	1960 – 2018 / monthly
• Cultivated area • Total tea production	Agricultural Output	TURKSTAT (1967-2018)	1968 – 2018 / yearly
1. Agricultural machinery and equipment 2. Oil price 3. Economic crisis	Complementary Variable	1. TURKSTAT (1967 – 2018) 2. Presidency Strategy and Budget Office, CBRT (1967 – 2018) 3. Author’s own compilation	1968 – 2018 / yearly

The other collected data group is agricultural data. To examine the impact on agricultural output and productivity, "Agricultural Structure and Production Statistics" published by TURKSTAT were used. These data covering the 51 years between 1967 and 2018 subject to the study are recorded in three different channels. Among these, statistics between 2004 and 2018 are available on the TURKSTAT website under "Crop Production Statistics" as an open-access database. Is it obtained statistics between 1991 and 2003 from TURKSTAT on demand. The statistics between 1967 and 1990 have been included in "Agricultural Structure and Output Statistics Publication," published by TURKSTAT as an annual book since 1967 until 1990. These publications have examined and the data digitized manually for the specified years. Although the raw data have been kept since 1967, the analysis started in 1970 because the data between 1967 - 1969 were not kept regularly. Yield data were calculated using total cultivated area and output variables. As a result, there are unit mismatches between datasets. For example, acreage and output data for tea are kept in hectares in some datasets and decares in others. The inconsistency between the datasets has been eliminated by making the necessary transformations. Within the scope of the analysis, yield calculations and analyzes were carried out on the output per 1000 hectares.

The third data category in the model is complementary variables. Complementary variables consist of other variables that are expected to affect agricultural output productivity. Considering the land conditions in which tea cultivation is made in Turkey, labor-intensive technology is primarily used, but agricultural mechanization stands out and is one of the most critical factors for tea cultivation. Therefore, the use of tractor and, accordingly, tractor equipment has misleading potential in variable selection. For this reason, labor-intensive agricultural equipment data, including spraying and irrigation equipment used. Equipment data is also formatted as total equipment per 1000 hectares to harmonize to cultivation data. It is expected that macroeconomic factors will affect agricultural output and yield through agrarian inputs. For this reason, oil prices (real price in USD) have been included in the model. Oil prices affect output and productivity through input prices and use. Finally, the effect of macroeconomic factors was tried to be controlled by including economic crises in the model. Therefore, crisis years are included in the model as a dummy. Agricultural equipment data was obtained from TURKSTAT sources in the same way as agricultural output data. Oil prices have been received from the resources of the CBRT and the Presidency Strategy and Budget Department.

Although factors such as fertilization and the farmer's education level also have an impact on yield, there is no data on these variables.

4. Analysis

The effect of climate change on agricultural output and yield has been studied in different models before. It has been created a response function to observe this effect. This response function constitutes the fundamental equation of empirical analysis (see equation 1)

(1) $\mathbf{y_{it} = f(c_{it}) + \alpha_1 t_{it} + b_1 v_{it} + x_i + e_{it}}$

Here, $f(c_{it})$ is the climate factors, including linear and quadratic forms (mean temperature, max temp, precipitation, frost day frequency, evapotranspiration). At the same time, t is agricultural technology proxied by total equipment or irrigation equipment per 1000 hectare. x_i is the provincial fixed effects, and e_{it} is the error term. Notation v refers complementary variables such as oil price, economic crisis dummy.

The study includes four different provinces (Rize, Artvin, Trabzon, Giresun). While studying the climate models, the vegetation period is taken as a reference in the use of the period for yield and output. The period in which the product grows is examined, and these values in the t_0 - t_1 period are used. Although there are studies are carried out on annual averages, the product growing season is vital for prediction calibration and precision. While tea can be grown in principal producer countries during the year, it is grown in Turkey for six months (Ministry of Agriculture and Forestry, 2020). Therefore, data for climate factors consists of a 6-month climate data average between April-September. For the frost day frequency calculation, July and August are not included. Since tea grows only in a specific region, a region dummy will not be used in the analysis.

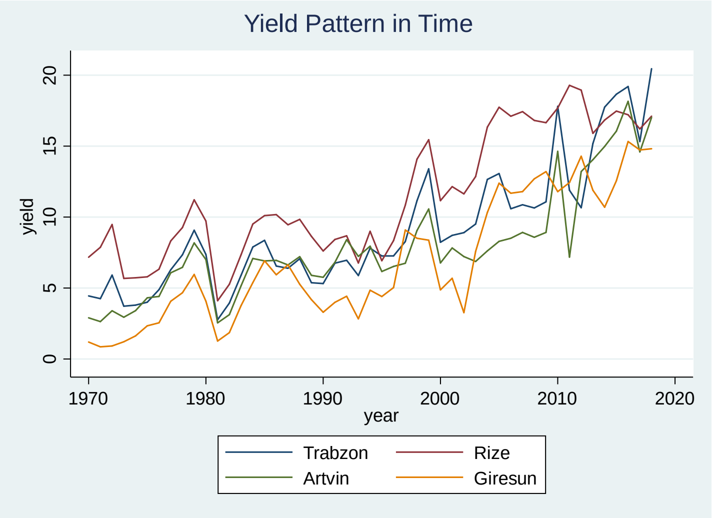
4.1. Descriptive Analysis

Tea is grown in a parallel zone between 42-North and 27-South and a plant with plenty of annual rainfall requests. Therefore, shoots occur intermittently, not continuously throughout the year. In cold seasons, which are not suitable for shoot formation throughout the year, shoot formation stops, leaf, and budding do not occur, so the plant goes into a dormant season (Kaçar, 1987).

Among the conditions affecting the yield, climatic conditions are at the top. The effect of climatic conditions on yield during the dormant period is much more limited than the growing period. Studies have shown that the climate demand for tea is abundant rain and sufficient temperature during the growing period. It is essential for tea yield that the annual precipitation is not less than 2000 mm, the precipitation amount in the growing season is not less than 1200 mm, and the precipitation distribution across the months is not irregular.

The temperature has also been found to positively affect tea yield in most of the studies. Temperatures below 14 degrees and above 40 degrees, high-temperature differences during the shoot period damage the tea and reduce the yield (Murat, 2017). On the other hand, the relative humidity should be 70% during the growing period (Kaçar, 2010). The temperature decreases the humidity after a certain point and reduces the yield. However, the precipitation regime of the Black Sea region is a factor that can compensate for the adverse effects of the humidity problem and, therefore, the temperature. Considering these optimum conditions, temperature, precipitation, frost day frequency, and potential evapotranspiration as a proxy of humidity will be interpreted.

Figure 2: Change in Yield Over Time



When the yield values for the sample are examined over 50 years, an increasing trend is observed in tea as in many agricultural products. This trend may be due to improving agricultural technology, fertilizer and soil conditions, irrigation, spraying, seeds, and increasing the level of farmer knowledge, as well as sometimes due to climatic conditions working in favor of yield. Figure 2 shows the change in yield values over time for the four provinces. Until the mid-2010s, it can be seen that the province with the highest yield per 1000 hectares was Rize, and in the last few years, the yield values converged for provinces. When the movements in the graph are examined, it is easily seen that the movements in the four provinces are in the same direction, and the magnitudes are close. Therefore, the highly correlated yield changes may have arisen due to the changes in climatic conditions, especially until the 2010s. Since the region is exposed to the same atmospheric events, the temperature and precipitation regime movements over the years have the potential to affect the crop yield directly. Since there are no sudden rise and fall movements in factors such as technology, fertilizer, irrigation, spraying, seeds, farmer knowledge, which are other factors that will affect the yield, it can be expected that this movement may have occurred due to changes in climatic conditions or less likely economic reasons.

As shown in Table 3, the province has the highest average tea yield in 50 years is Rize. The average yield per hectare between 1968 and 2018 for Rize is 11.8 kilograms. This figure means approximately 25% higher yields per hectare than Trabzon and about 45% and 67% higher than Artvin and Giresun, respectively. This situation may result from the importance given to tea cultivation in Rize, and the opportunities provided by the soil and climatic conditions of Rize may have been a factor that facilitated the priority given to tea cultivation and the sector to take a form with high economic returns. However, the determination of this relationship is not the subject of the study. In Table 3, the average yield values for 10-year periods can be seen in kilogram per hectare. As we get closer to today, it clearly seems that the gap is closing. That situation can be interpreted as an increase in the amount of product per planted area for the remaining provinces due to agricultural technology and mechanization, cultivation techniques, correct use of fertilizers and seeds, and farmer awareness. On the other hand, it is undeniable that the effect of climatic conditions on yield had a more important place in the past years. When more traditional farming methods were using, the most crucial factor in productivity was climatic conditions in the past decades. Climatic conditions were followed by features such as the use of agricultural equipment, soil structure, and product characteristics.

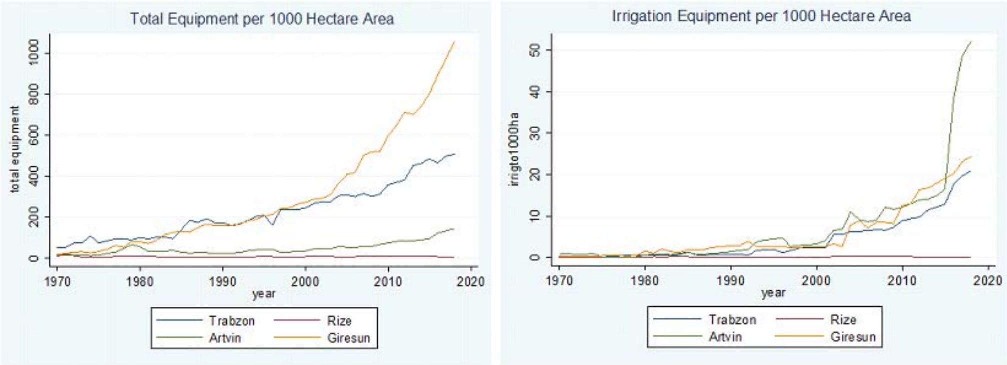
Table 3: Yields per 1000 hectares (in kg)

	68 - 78	*78 - 88*	*88 - 98*	*98 - 08*	*08 - 18*	*1968 - 2018*
Rize	7,3	8,7	8,9	14,9	17,3	**11,5**
Trabzon	4,9	6,5	7,2	10,7	15,8	**9,1**
Artvin	4,1	6,1	1,9	8,1	13,9	**7,9**
Giresun	2,2	4,7	5,1	8,9	13,1	**6,9**
Ordu	1,3	1,6	7,1	2,7	9,1	**3,3**

Source: Author's own calculations by using TURKSTAT database.

Total agricultural equipment and irrigation equipment data indicating agricultural mechanization, affecting agricultural productivity apart from climate among complementary variables, are shown in figure 3. The total number of the equipment has increased rapidly since the mid-1990s. It is seen that Giresun and Trabzon differ from Artvin and Rize because hazelnut farming is widespread in Trabzon and Giresun, and the use of equipment in hazelnut farming is more common.

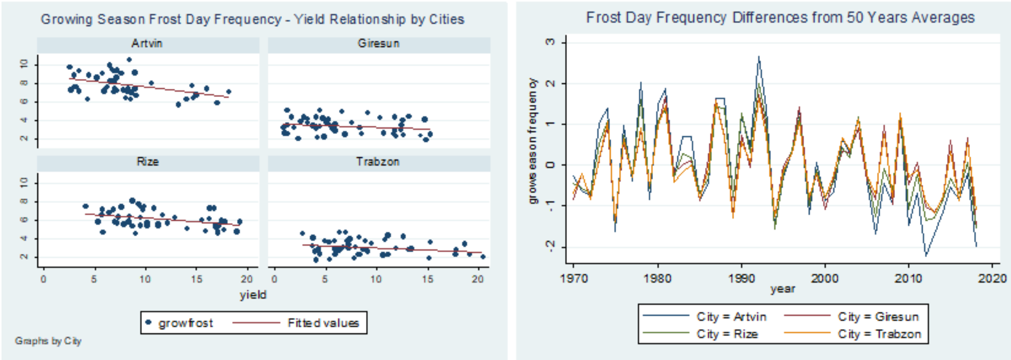
Figure 3: Total Equipment and Irrigation Equipment Changes Over Time



One of the greatest threats for almost all plant products is the frost events encountered during the vegetation period, which in case of frost, the plant turns brown, and shoots die. At temperatures below 15 degrees, the plant dies completely (Kacar, 2010). The relationship between yield and frost frequency can be seen in figure 4. As expected, and it can be suspected that there is a negative relationship between frost frequency and yield, especially for Artvin and Rize. Figure 5 shows how much the frost events encountered during the growing season deviate from the 50-year averages. It reveals that the frost frequency realized during the period decreased for the sample group. Especially with the 2000s, there is a downward deviation. This situation gives rise to the expectation that declining frost events will have a positive effect on yield.

It is expected that evapotranspiration and yield show a positive relationship. The relative humidity demand of tea is high, and relative humidity is one of the indispensable conditions for efficient tea harvesting. For this reason, tea agriculture is stuck in narrow and unique geography. Relative humidity brings with it transpiration and evaporation. For this reason, it is expected that will have a positive effect on yield (see figure 5).

Figure 4: Frost Frequency Representations for Sample Group



Precipitation is one of the most significant climate variables for tea. It can be seen that the amount of precipitation that our sample cities receive during the crop growing season and especially in the spring increases over time. For Rize, Trabzon, and Artvin, precipitation amounts have increased significantly. Even when extreme events are excluded, the precipitation regime has changed in recent years, and average increases of up to 30%. This situation includes potential positively affects yield if the equal distribution of precipitation during the growing season is ensured to a certain extent. However, even though precipitation has increased for the Eastern Black Sea region, many studies have shown that these precipitations fall in very narrow time intervals, and this irregularity is caused by climate change. Although this erratic precipitation regime has the potential to have a devastating effect on tea yield, however, it is the focus of further analysis. Figure 6 and 7 shows the growing season precipitation in time for four provinces, and it can be seen that both the frequency and intensity of precipitation increased, especially as of the 2000s. When the figure 7 is examined, the height and frequency of the upward peaks are striking. Our study focuses on the effect of long-term trend movements on yield and as long as the precipitation does not exceed the maximum threshold, it is expected to affect the yield positively. Figure 6 gives an idea about a positive relationship between precipitation and yield in the crop growing season.

Figure 5: Potential Evapotranspiration and Yield Relationship

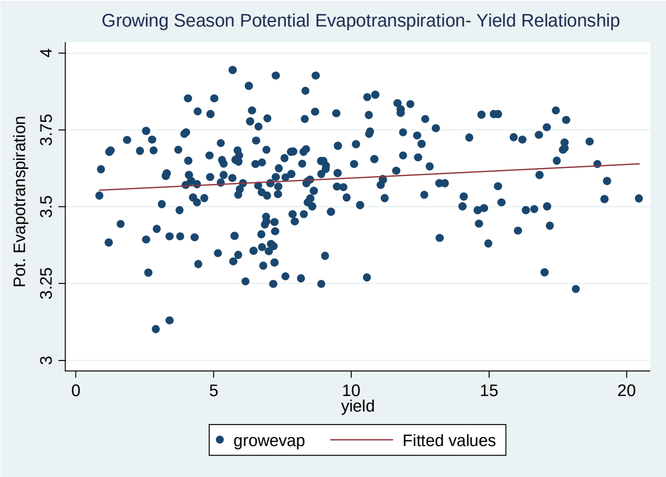


Figure 6: Growing Season Precipitation and Yield Relationship

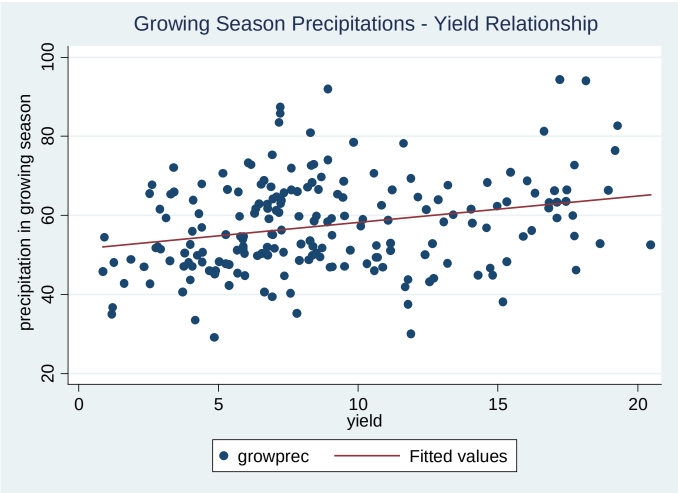
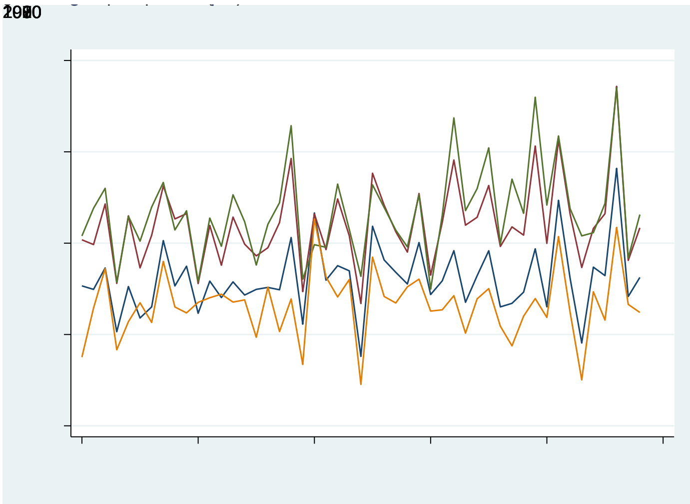


Figure 7: Growins Season Precipitation Regime



The last climate variable which it will be examined is temperature. The temperature has different variations as average, maximum, minimum and differences among the variations. All of the identified provinces have witnessed increases in average temperatures between 1 and 2 degrees in the past 50 years. The change in average temperatures over a 50-year period is presented in figure 8 on a province basis. Especially the occurred high temperatures after the 2010s are striking. Although this situation is not a heartwarming scenario for the world, it is a plot with a possibility of positive results for tea yield. Tea is a plant that likes high temperatures during the growing season. As shown in figure 9, the direction of the relationship between average temperature and yield is the same. Significant differences are observed when the average temperature shown in figure 10 is compared between the first ten years of 1968 - 1978 and 2008 - 2018. For example, while the average growing season temperature (April – September) for Trabzon in the first ten years was 15.37 degrees, it increased to 16.41 degrees with an increase of 1.04 (6.7%) degrees in the last ten years. This increase is 1.2 (8.3%) for Rize, 1.05 (8.3%) for Artvin and 1.08 (7.3%) for Giresun. The tea plant, which has a tolerance to a temperature of 40 degrees, can be positively affected by temperature increases as long as the humidity in the air is sufficient. Therefore, temperature increases on tea yield has still room for improvement.

Average temperature and maximum temperature are correlated with each other. The maximum temperature shows the same direction as the average temperature with yield in the whole sample and the provinces separately. Data shows that summer temperatures have increased by 1.4 and 1.5 degrees celsius for four provinces and there are upward deviations from the averages. Numbers also provide an idea of temperature anomalies, as the maximum temperature changes are striking especially in summer.

Figure 8: Mean Temperature Changes for Growing Season

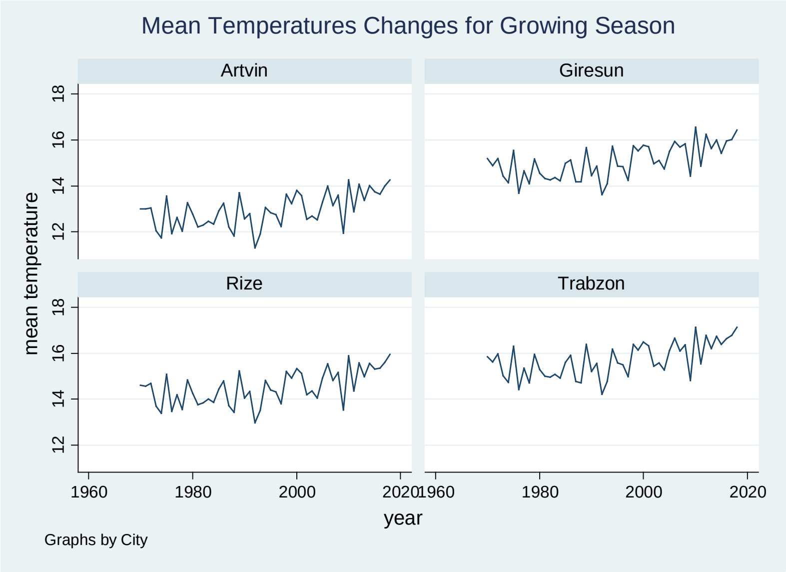


Figure 9: Temperature & Yield Relationship

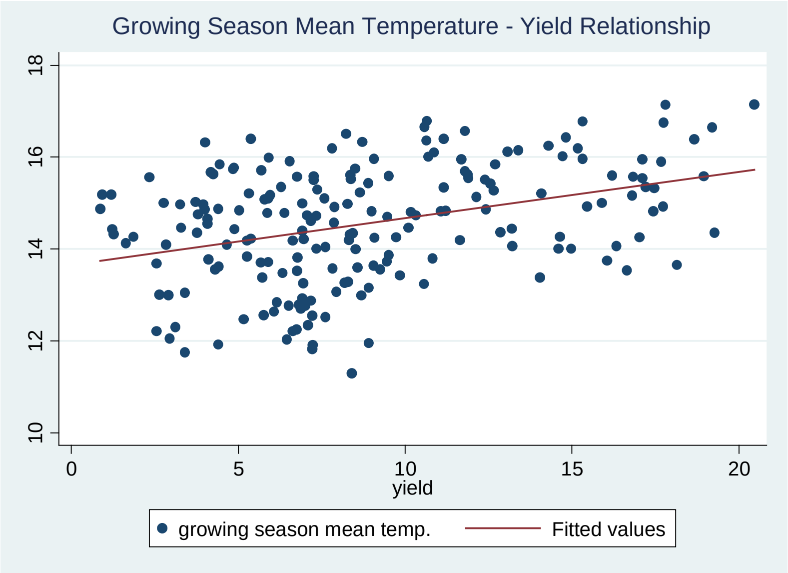
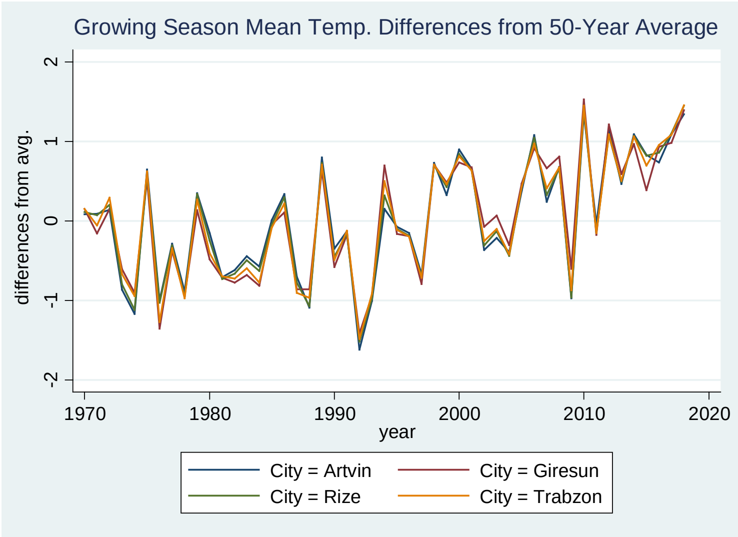


Figure 10: Deviations From the Average for Mean Temperature



4.2. Empirical Analysis

We are interested in the direction of the relationship in the study. In such researches, point-shot estimations do not give very healthy results and for numerical predictions, micro-scale, even lab-level studies are more effective. Therefore, the coefficients will not be interpreted in terms of quantity; their sign and significance levels will be considered.

The data structure was checked before the analysis. The relationship between climate and yield mostly has a non-linear relationship. In order to determine the data form, scatter plots were examined for both in fit and quadratic lines and it was observed whether the relationship was linear or non-linear. As there are minimum and maximum thresholds for climate, the created response function can give different outputs in value ranges outside these thresholds. Since the linear relationship may not hold under all conditions due to the nonlinear response of crop growth to climate, it includes quadratic forms for each selected climate variable to account for the nonlinear effects. However, this situation has created a multicollinearity problem. Due to the high correlation in the main model, multicollinearity is obtained since linear and quadratic forms are used together. The demeaning process has been implemented to eliminate this challenge. A conversion ladder is used when necessary, especially for highly fluctuated variables and variables with the unit root problems. Influential/unusual data, normality of residuals and linearity&non-linearity are checked normatively.

Log form is used due to yield fluctuations and found no unit root for the dependent variable. The total equipment graph shows a regular increase over time and is non-stationary. This problem has been overcome with log transformation. Log form is allowed to soften dramatic increase and outlier values for machinery&equipment as well. Climate data is stationary as foreseen, therefore no transformation was performed. Other variables do not have the unit root problem. Two other potential problems noted during the analyzes are heteroscedasticity and serial correlation. Due to the long time dimension, serial correlation problem occurs in most of the models. We carried out controls for the determined analysis scenarios and alternative models, and accordingly, selected the proper estimator. Another problem that has been frequently considered in the panel data literature in recent years is cross-sectional dependency. Panel time series econometrics have evolved from the assumption that panel units are cross-sectionally independent to second-generation methods and tests. Today, the view that concerns are common to cross-sectional units is accepted (Eberhart, 2009). It marked common factor approach which error term includes unobserved common factors. As stated in the previous sections, tea farming is confined to narrow geography. This situation suggests the existence of CSD, considering the geographical proximity of the sample provinces. Furthermore, CSD testing for alternative models demonstrated unobserved factors/shocks, which it was taken into account when selecting the estimator.

After deciding on the analysis method for diagnosis, it was determined which model and estimator to use, and it was decided to use fixed effect, GLS or OLS. Although our basic scenario focuses on four tea-growing provinces in 1970 - 2018, alternative scenarios and robustness check analyses were determined. As a result, there are no provinces differences in the analyses. At the same time, there are no seasonal differences due to the narrow growing season and geographical limitations. This means that no dummy is used for the specified variables. On the other hand, there are some thresholds for climate change in long time periods. This situation has the potential to affect the analysis results and approach. Climatic events fluctuate over long periods, and the earth cyclically experiences its usual cooling and warming periods. This cycle has changed with human intervention, and the warming period has accelerated. Therefore, in addition to examining a period of approximately 50 years as a whole, this 50-year period was divided into two as cold and warm periods in order to observe the effect of climatic differences over time. Coincidentally, and fortunately, 1993, when the pattern change took place, divides the 50-year period dataset into two equal parts.

Table 4: Regression Results for Wide Time Period

1970 – 2018 Analysis Results. (Main Model)

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

IABLES	(1) lnyield	(2) lnyield	(3) lnyield	(4) lnyield	(5) lnyield	(6) lnyield	(7) lnyield	(8) lnyield
gmean	0.406***		0.435***	0.173***	0.427***	0.175***		
	(0.0763)		(0.0653)	(0.0438)	(0.0637)	(0.0431)		
gmean2	0.0375**		0.0337**	0.0038	0.0303**	0.00385		
	(0.0145)		(0.0151)	(0.0154)	(0.0118)	(0.0139)		
gprec		0.00868**	0.0162***	0.0049**	0.0171***	0.00538**	0.0146**	0.0034
		(0.00173)	(0.0059)	(0.0023)	(0.0057)	(0.0021)	(0.0068)	(0.0022)
gprec2		0.00031**	1.24e-05	8.13e-05	6.57e-05	0.0001	0.0001	0.0001
		(8.40e-05)	(0.0002)	(7.76e-05)	(0.0002)	(8.17e-05)	(0.0002)	(8.57e-05)
gfrost							-0.162**	-0.0655**
							(0.0685)	(0.0264)
gfrost							-0.0003	-0.001
							(0.0078)	(0.005)
gevap					0.677	0.189	0.941*	0.209
					(0.415)	(0.212)	(0.522)	(0.217)
gevap2					-1.023	-0.825	-0.551	-0.694
					(0.841)	(0.576)	(1.036)	(0.548)
lnequip				0.562***		0.556***		0.632***
				(0.0615)		(0.0556)		(0.0439)
oilprice				-0.0899		-0.0643		-0.0478
				(0.0746)		(0.0734)		(0.0868)
crisis				-0.127		-0.129		-0.137
				(0.0874)		(0.0885)		(0.0834)
constant	1.963***	2.001***	1.968***	-0.259	1.993***	-0.218	2.020***	-0.526**
	(0.0855)	(0.00598)	(0.0837)	(0.286)	(0.0867)	(0.261)	(0.105)	(0.217)
Estimator	Fixed effect estimator (panels corrected standart errors, AR1)							

The measurements and signal analysis studies revealed that the cool period ended between 1992 and 1993, and low temperatures were recorded during this period. After this period, a significant warming trend is observed in all alternative models (Tayanç, 2009). For this reason, alternative scenario-based models were run for the periods 1970 - 1993 and 1993 - 2018 to decompose the term effect. Within the scope of robustness check, parameter error terms were calculated by bootstrapping method. Bootstrapping is a statistical procedure that resamples a single dataset and generates many simulated samples. That allows users to calculate standard errors, construct confidence intervals, and perform hypothesis testing for numerous types of sample statistics. Robustness check results are also given as Table A.1, A.2 and A.3 in appendix. Table 3 reflects our base analysis results.

The first variable that was examined is temperature, and gmean indicates growing season mean temperature. It is seen that the average temperature increase over 49 years positively affects tea yield (Table 4). Results showed a positive effect at a high significance level for all equations in the main model. The period from which this effect originates can be seen when Table 5 and Table 6 are examined. The effect of temperature in 1970 – 1993 has insignificant or very low significance levels for many models (T5). Table 6 reveals a strong positive impact on yield in the 1993 – 2018 period when warming accelerated. That result shows that rising temperatures make a positive contribution to tea yield in line with expectations. It is seen that the increase in yield mostly comes from in the second period, which it is called the warming period.

It is seen that precipitation has a significant positive effect over a 50-year period (see T4). However, it is discerned that this effect stems mainly from the period before 1993. Contrary to temperature, the effect of precipitation on yield after 1993 weakened or even disappeared. When it is looked at Figure 7, it can be seen more anomalies in the amount of precipitation after the 2000s, rather than a decrease in level. In particular, the upward wave-lengths have reached levels that they have not reached before for Rize, Artvin, and Trabzon. Regions receiving heavy rainfall for a year receive deficient rainfall the following year. Tea is a rain-loving product, but as stated before, there is a demand for precipitation that is equally distributed during the growing season. Therefore, it can be interpreted that extreme precipitation has a negative effect on yield over time. It is also a fact that extreme precipitation indirectly causes landslides and deterioration in the arable land structure, which puts pressure on yield.

Table 5: Regression Results for Cool Period

1970 – 1993 Analysis Results. (Main Model)

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

VARIABLE	(1) lnyield	(2) lnyield	(3) lnyield	(4) lnyield	(5) lnyield	(6) lnyield	(7) lnyield	(8) lnyield
gmean	-0.0023		0.123**	0.160***	0.0932*	0.141*		
	(0.106)		(0.0589)	(0.06)	(0.0463)	(0.0734)		
gmean2	0.0095		0.006	0.0236	0.0136	0.0264		
	(0.0214)		(0.0189)	(0.0237)	(0.0178)	(0.0242)		
gprec		0.0226***	0.0307***	0.0296***	0.0312***	0.0297***	0.0219***	0.0226**
		(0.0053)	(0.008)	(0.0085)	(0.0065)	(0.0085)	(0.0078)	(0.0084)
gprec2		-0.0006	-0.0005	-0.0004	-0.0006	-0.0004	-0.0006	-0.0004
		(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
gfrost							0.0317	0.0231
							(0.0323)	(0.029)
gfrost							-0.0075	-0.0085
							(0.0049)	(0.0083)
gevap					0.364	0.202	0.588	0.459*
					(0.472)	(0.509)	(0.413)	(0.259)
gevap2					-1.513*	-0.691	-1.746**	-1.398
					(0.843)	(1.419)	(0.710)	(0.882)
lnequip				-0.0530		-0.0519		0.0039
				(0.0546)		(0.0554)		(0.0548)
oilprice				0.0145*		0.0126		0.0069
				(0.0078)		(0.0085)		(0.0121)
crisis				-0.161		-0.134		-0.0709
				(0.244)		(0.249)		(0.290)
constant	1.613***	1.685***	1.671***	1.590***	1.703***	1.633***	1.761***	1.623***
	(0.113)	(0.0785)	(0.0846)	(0.215)	(0.111)	(0.213)	(0.0978)	(0.281)
Estimator	Fixed effect estimator (Panels corrected standart errors, AR1)							

It can be mentioned that frost events have a negative effect on yield in line with expectations. The effect of frosts seen in the second period, when the daytime temperature differences increase, on tea yield is more significant in the negative direction. It could not be reached consistent results on evapotranspiration. Therefore, it is hard to interpret it. It has been seen that it has a positive effect on yield, albeit low in a few models, but it seems the level of significance dissappears when the other variables is included into the model

As expected, the positive effect of agricultural machinery & equipment on yield can be consistently seen for the alternative estimations in warm period. Temperature and agricultural equipment are the variables with the highest impact and explanatory power in all models coherently. While the effect was pronounced and high after the 1990s when mechanization accelerated, and agricultural technologies developed, the equipment was not significantly affected in the pre-1993 model. Agricultural equipment data shows a parallel development with irrigation and spraying data. Multicollinearity problem arose when they were included in the model together. Therefore, only agricultural equipment variable is shown in the results since when inserted into the model separately, very similar results emerged. While no significant effect of oil prices on yield was observed, the impact of the economic crises that started in 1994 can be seen, albeit slightly. The statistically meaningless oil prices may have resulted from the lack of advanced agricultural equipment such as tractors and combines in tea farming. The mechanism affecting the yield of the crisis works through production inputs. The fact that the farmer could not make the necessary investments and operations for fertilizer, seed, labor supply, and plant care may have a negative effect on the yield. This is much lower for tea than for traditional agricultural products such as wheat, barley, or fruit since the tea production in Turkey does not include complex maintenance, processing, and collection stages.

Table 6: Regression Results for Warm Period

1993 – 2018 Analysis Results. (Main Model)

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

VARIABLE	(1) lnyield	(2) lnyield	(3) lnyield	(4) lnyield	(5) lnyield	(6) lnyield	(7) lnyield	(8) lnyield
gmean	0.309*** (0.0875)		0.347*** (0.0766)	0.130** (0.0505)	0.352*** (0.0721)	0.132*** (0.0424)		
gmean2	0.0098 (0.0142)		0.00523 (0.0174)	0.0007 (0.0099)	0.0066 (0.0171)	0.0012 (0.0097)		
gprec		0.0023* (0.0051)	0.0099** (0.004)	0.0036 (0.0022)	0.0087* (0.0047)	0.0019 (0.0022)	0.0057 (0.005)	-0.0006 (0.003)
gprec2		5.81e-05 (0.0001)	1.41e-06 (0.0001)	-7.93e-06 (5.05e-05)	5.87e-06 (0.0001)	-2.60e-05 (6.47e-05)	1.57e-05 (0.0002)	-1.51e-05 (7.92e-05)
gfrost							-0.141*** (0.0496)	-0.0219* (0.0260)
gfrost2							-0.0058 (0.0073)	-0.0028 (0.0043)
gevap					-0.295 (0.322)	-0.423* (0.220)	-0.145 (0.375)	-0.398 (0.249)
gevap2					-0.471 (0.937)	0.0775 (0.523)	0.237 (1.256)	0.311 (0.579)
lnequip				0.500*** (0.0779)		0.483*** (0.0776)		0.563*** (0.0851)
oilprice				0.0017* (0.0009)		0.0021** (0.0009)		0.0023* (0.0012)
crisis				-0.154* (0.0799)		-0.147* (0.0767)		-0.176** (0.0708)
constant	2.362*** (0.0901)	2.367*** (0.106)	2.368*** (0.0816)	0.0707 (0.378)	2.378*** (0.0767)	0.124 (0.369)	2.392*** (0.103)	-0.232 (0.405)
Estimator	Fixed Effect Regression (Driscoll Kraay Standart Errors)							

The quadratic forms of the climate variables give meaningless results in the scenario compared to the linear terms. Although the direction is the same, turning the coefficients into insignificant indicates no significant effect of the relevant variable on the yield at values beyond the threshold point. Robustness tests have been performed beyond our base model. Outputs can be seen in the appendix as Table A.1, A2. and A.3, respectively.

Only independent effects for the linear forms of the variables were examined for 1970 - 2018 in the Extension 1 scenario. The linear model results support the main models. The positive effect of temperature variations (mean, maximum and max-min difference) and precipitation alongwith the negative effect of frost on yield can be seen. When evapotranspiration, which is insignificant in the main model, is examined alone, it can be seen that it positively affects yield in line with expectations. The results of extension 2 which it is called temperature model (see table A.2), in which only the temperature variables are analyzed, show that the increase in the average temperature, the maximum temperature, and the temperature difference positively reflects the yield. In addition to irrigation equipment, it can be observed that the total equipment has similar results with the base scenarios on yield. The bootstrapped results in our Extension 2 model also reveal the same results as main samples and base scenarios, indicating the consistency and robustness of the analysis. Extension 3 is a continuation of extension 2 and aims to reveal the effect of variables other than temperature including bootstrapped samples. Here, while the impact of factors such as precipitation, frost, and evaporation alone is in line with the expectations, it is seen that the coefficients become meaningless when the total irrigation equipment or total equipment is included in the model. This result indicates that machine equipment has a powerful and exclusive effect to other variables on yield. On the other hand, it is seen that the temperature variables and the equipment data included in the equation do not have a similar effect on the temperature in the extension 2 model. Considering the main and alternative scenarios, it can be asserted that temperature and mechanization in agriculture have a decisive impact on yield. The results it have been reached are compatible with both our expectations based on our observations and the intuitions it has been obtained from the descriptive results. They are satisfactory on that sense.

5. Conclusion and Recommendations

Rather than the growing interest in climate change, the significant impacts that started today and will emerge in the future prompted me to carry out this study. Tea is an agricultural product that has an economic value and a social function in Turkey. However, studies on it are very limited. Sadly, there has not been a macro-scale study for Turkey, with an economic perspective on the future projections and the impact of climate on the product, but it also presents an untouched field of research.

The literature needs studies focusing on the socio-economic outputs of the macro-scale climate crisis as much micro-scale farm-based or phenological studies as. Within the scope of the study, it was tried to measure how the changes in climatic conditions have an effect with a retrospective analysis rather than future predictions. It is beneficial to examine the future projections and the economic reflections of this situation as follow-up studies. The effects of climate variables such as temperature, precipitation, frost events frequencies, and evapotranspiration between 1970 and 2018 on tea yield were examined by considering agricultural mechanization development and macroeconomic conditions. Robustness tests were also carried out in the study, which by using different models and scenarios. Based on the obtained results, it was strongly observed that the temperature increase positively affected the tea yield. The general opinion is that rising temperatures will have a negative effect on agricultural output through the drought risk. Although this view is accurate for many crops and geographies, each crop's cultivation conditions and regional characteristics may cause different results. If the necessary precipitation and humidity are provided, the tea yield, which is resistant to temperatures up to 40 degrees, was positively affected by the temperature increases over time. It is seen that precipitation and humidity increase the yield, and frost events infest the plant. To distinguish the effect of climate change more clearly, the time period, divided into two intervals as cold and warm periods, revealed how the temperature, frost events, and precipitation change and affect due to the differentiation of climate movements. The irregularity of precipitation resulting from climate change has led to the loss of the positive effect of precipitation on yield. On the other hand, the decrease in frost frequency has positively impacted the yield and temperature. While the boom in the use of agricultural equipment as complementary variables increases the yield, a slight negative effect of the economic crisis has been observed. Six models and a dozen equations run revealed that temperature and agricultural equipment were the most important factors for yield.

Although tea requires precipitation, these results contain warnings that irregular precipitation, which is expected to increase in the future, may decrease the yield. The temperature rise may positively affect yield up to a certain level, but the effect may turn negative after the threshold. The temperature is having another indirect impact on tea. Tea grows in the Black Sea for six months and the cold winter season provide natural protection from pests that have a devastating effect on the plant. However, the increase in winter temperatures will awaken some diseases and adversely affect the yield.

Considering the growth in the market share of tea, which directly or indirectly contributes to the employment of approximately a million people, it is useful to include measures to protect it from the harmful effects of excessive precipitation. Using irrigation systems for seasons when the precipitation is low is vital for meeting the plant's water demand. Considering that the majority of tea producers are smallholders, it is necessary to take appropriate steps and measures to stabilize the income sources of these small and medium-sized producers. As it is mentioned in the previous section, the labor force participation of women in the Eastern Black Sea region is very high. The fact that the gardens become unusable due to the deteriorated land structure will bring the risk of reducing labor force participation. A significant share of the workers in the tea gardens is women. This situation brings forth negative scenarios in terms of labor force participation. It also carries the danger of emigration from the region, where economic activity is already confined to a few sectors with very restrained economic activity, causing different problems. Therefore, there is a need to examine new research and models to clarify the future effects.

As a policy measure, precautions and steps such as pilot field studies can be taken to increase the capacity of tea producers on climate change adaptation and mitigation with public initiative and private sector support and to eliminate existing adverse effects. Furthermore, the impact of these studies would increase by conducting pilot sustainability studies together with private sector representatives. On the other hand, an extra climate support framework can be created to compensate for the farmers' losses who have lost their income by the public authorities in cooperation with different stakeholders.

References

Bogazici University and Rize Municipality, Improving Women's Labor Force Awareness in the Agricultural Sector in Turkey in a Changing Climate Project; (2018), "Impact of Climate Change on Tea Yield Report", Retrieved January 2020 url: https://www.iklimin.org/wp-content/uploads/2018/01/Brief_Econometric_Analysis_Report.pdf

BORE, J. K., and NYABUNDI, K.W. (eds); (2016), "Impact of climate change on tea and adaptation strategies (Kenya)," in Report of the Working Group on Climate Change of the FAO Intergovernmental Group on Tea, (Rome: Food and Agriculture Organization of the United Nations), pp. 45–60.

BÜTÜNER, M.; (2019), "Küresel İklim Değişikliğinin Fındık ve Çay Tarımına Etkisi", Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi

CHESEREK, B. C., ELBEHRI, A., and BORE, J; (2015), "Analysis of links between climate variables and tea production in the recent past in Kenya", Donnish J. Res. Environ. Stud. 2, pp. 005–017.

CRU - University of East Anglia Climatic Research Unit (2019), data downloaded from https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_4.02/

EBERTHARD, M. and BOND, S; (2009), "Cross-section dependence in nonstationary panel models: a novel estimator.", MPRA Paper No. 17692, online at https://mpra.ub.uni-muenchen.de/17692/

FAO; (2015a), "Kenya's tea sector under climate change: An impact assessment and formulation of a climate smart strategy", by Elbehri, A., B. Cheserek, A. Azapagic, D. Raes, M. Mwale, J. Nyengena, P. Kiprono, and C. Ambasa. Rome, Italy.

FAO; (2015b), "Socio-economic implications of climate change for tea producing countries", by CHANG K. And BRATFOLL, M. Trade and Market Division, Rome 2015.

FAO; (2018), "FAOSTAT statistical database", Rome: FAO, url: https://www.fao.org/ faostat/en/#data

FAO, Intergovernmental Group on Tea; (2018), "Current Market Situation and Medium Term Outlook", Twenty Third Session. Hangzou, China, 17-20 May 2018

FAO and CAAS; (2021), "Carbon neutral tea production in China – Three pilot case studies", Rome

HARRIS, I., JONES, P., OSBORN, T. and LISTER, D. (2014), Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset. Int. Journal of Climatology, v34: 623-642. doi:10.1002/joc.3711.

IPCC; (2018), "Global Warming of 1.5^0 C. An IPCC Special Report on the Impacts of Global Warming".

İSTİKBAL, D; (2020), "Küresel Çay Ekonomisi ve Türkiye", Kriter Dergi, V.48, https://kriterdergi.com/ekonomi/kuresel-cay-ekonomisi-ve-turkiye

KACAR, B; (1987), "Çay Biyokimyası ve İşleme Teknolojisi", Nadir Kitap, 387 sayfa. Ankara.

KACAR, B; (2010), "Çay Bitkisi Biyokimyası Gübrelenmesi İşleme Teknolojisi", Nobel Yayın, Yayın No: 1549, Fen Bilimleri: 107, Nobel bilim ve Araştırma Merkezi Yayın No: 64, 355 sayfa, Ankara.

Ministry of Agriculture and Forestry Crop Production General Directorate; (2020), "2020 Tea Assessment Report", https://www.tarimorman.gov.tr/BUGEM/Haber/565/Urun-Masalari-Cay-Findikincir-Kayisi-Kiraz-Ve-Uzum-Urun-Degerlendirme-Raporlari-Yayimlandi", 17.07.2020

MURAT, E; (2017), "Çayda Farkli Tarihlerde Çirpmanin Hasat Tarihi, Verim ve Kalite Özelliklerine Etkisi", Ordu Üni. Fen Bilimleri Ens. Yüksek Lisans Tezi, Ordu.

ÖNÇIRAK, M; (2019), "Çay Sektörü ve Türkiye Ekonomisi", Master Thesis, Bursa Uludag University.

Presidency Strategy and Budget Office; (2019), "Main Economic Indicators", url https://www.sbb.gov.tr/temel-ekonomik-gostergeler/

Rize Commodity Exchange Market; (2021), "Turkish Tea Sector Recent Situation Report - 2021".

SCOTT, ERIC and LI, XIN and WEI, JI-PENG and KFOURY, NICOLE and MORITOMO, JOSH and GUO, MING-MING and AGYEI, AMMA and ROBBAT, Jr, A. and AHMED, SELENA and CASH, SEAN and GRIFFIN, TIMOTHY and STEPP, JOHN and HAN, WENYAN and ORIANS, COLIN and FRIEDMAN, DOROTHY; (2020), "Changes in Tea Plant Secondary Metabolite Profiles as a Function of Leafhopper Density and Damage", Frontiers in Plant Science, v.11. doi:10.3389/fpls. 2020. 00636.

Statista, (2021), "Statista Consumer Market Outlook Tea Report", Release Date: March 2021, url: https://www.statista.com/outlook/cmo/hot-drinks/tea/worldwide

TAYANÇ, M. et all; (2009), "Climate Change in Turkey for the Last Half Century", Climatic Change, v. 94, pp.483–502

The NCAR Command Language (Version 6.6.2) [Software] (2019), Boulder, Colorado: UCAR/NCAR/CISL/TDD, doi:10.5065/D6WD3XH5.

TURKSTAT; (2018), "Crop Production Statistics", url: https://data.tuik.gov.tr/ Kategori/GetKategori?p=Tarim-111

TURKSTAT; "Agricultural Structure and Output Statistics", Volume 1967 – 1990 Annual Publications, TURKSTAT Printing Division

ZEYDAN, U. and LİSE, Y., (2020), "Fındık, İklim Değişikliği ve Çevresel Etkiler Türkiye Raporu"

Appendix

Table A.1: Robustness - Regression Results for Linear Relationship

1970 – 2018 Analysis Results Extension 1.
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) lnyield	(2) lnyield	(3) lnyield	(4) lnyield	(5) lnyield	(6) lnyield	(7) lnyield	(8) lnyield	(9) lnyield
lngmean	5.744***						2.199***	2.235***	
	(1.173)						(0.662)	(0.590)	
lngmax		7.347***							
		(1.434)							
lngmaxmin			0.399***						
			(0.0825)						
lngprec				0.819***				0.130**	0.897**
				(0.242)				(0.101)	(0.367)
lngfrost					-0.548*			-1.066*	-0.695**
					(0.292)			(0.737)	(0.294)
lngevap						2.716**		0.566***	3.338*
						(1.119)		(0.0826)	(1.897)
lnequip							0.585***	-0.122**	
							(0.0592)	(0.0942)	
oilprice							-0.103	-0.176*	
							(0.0681)	(0.0924)	
crisis							-0.124	-5.319**	
							(0.0843)	(1.961)	
constant	-13.34***	-20.33***	-8.766***	-1.276	2.864***	-1.444	-6.218***	-5.319**	-4.784
	(3.147)	(4.377)	(1.666)	(1.063)	(0.480)	(1.568)	(1.664)	(1.961)	(3.187)
Estimator(s)	Dris-kraay standart errors fixed effect estimator, cross-sectional time-series FGLS regression (AR1, heteroskedastic)								

Table A.2: Robustness – Regression Results for Temperature Variables

1970 – 2018 Analysis Results Extension 2. (Temperature Model)
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) lnyield	bootstr lnyield	(2) lnyield	bootstr lnyield	(3) lnyield	bootstr lnyield	(4) lnyield	bootstr lnyield	(5) lnyield	(6) lnyield
gmean	0.406***	0.406***	0.137***	0.137***						
	(0.0763)	(0.0392)	(0.0486)	(0.0361)						
gmean2	0.0375**	0.0375*	0.0061	0.0061						
	(0.0145)	(0.0200)	(0.0121)	(0.0130)						
gmax					0.352***	0.352***	0.129***	0.129***		
					(0.0640)	(0.0331)	(0.0403)	(0.0303)		
gmax2					0.0366**	0.0366**	0.0024	0.0024		
					(0.0140)	(0.0174)	(0.0116)	(0.0126)		
gmaxmin									0.273***	0.290***
									(0.0724)	(0.0765)
gmaxmin2									-0.111	-0.113
									(0.0687)	(0.0688)
lnequip			0.467***	0.467***			0.461***	0.461***	0.611***	0.598***
			(0.0460)	(0.0691)			(0.0477)	(0.0684)	(0.0410)	(0.0460)
lnirrigation			0.0814***	0.0814***			0.0803***	0.0803***		
			(0.0185)	(0.0277)			(0.0168)	(0.0271)		
oilprice			-0.0664	-0.0664			-0.0743	-0.0743		-0.146**
			(0.0722)	(0.0619)			(0.0690)	(0.0612)		(0.0659)
crisis			-0.105	-0.105			-0.103	-0.103		
			(0.111)	(0.0774)			(0.109)	(0.0761)		
constant	1.963***	1.963***	-0.0015	-0.0015	1.964***	1.964***	0.0298	0.0298	-0.451**	-0.378*
	(0.0855)	(0.0603)	(0.226)	(0.313)	(0.0841)	(0.0556)	(0.232)	(0.310)	(0.190)	(0.213)
Estimator	Fixed effect within estimator, panel corrected standart errors									

Table A.3: Robustness – Regression Results for Non-Temperature Climate Variables

1970 – 2018 Analysis Results Extension 3. (Non-Temperature Variables)
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) lnyield	bootstr lnyield	(2) lnyield	bootstr. lnyield	(3) lnyield	bootstr lnyield	(4) lnyield	bootstr lnyield	(5) lnyield	bootstr lnyield	(6) lnyield	bootstr lnyield
gfrost	0.457	0.457	0.313	0.313								
	(0.297)	(0.621)	(0.392)	(0.349)								
gfrost2	-0.342***	-0.342**	-0.196	-0.196								
	(0.118)	(0.214)	(0.177)	(0.141)								
gevap					0.724**	0.724**	0.0726	0.0726				
					(0.353)	(0.362)	(0.212)	(0.162)				
gevap2					-2.563	-2.563	-0.235	-0.235				
					(1.995)	(1.990)	(1.241)	(1.239)				
prec									0.0087**	0.0087*	0.0011	0.0011
									(0.0017)	(0.0045)	(0.0028)	(0.0027)
prec2									0.0003**	0.0003	5.04e-06	5.04e-06
									(8.40e-05)	(0.0002)	(0.0002)	(0.0002)
lnequip			0.509***	0.509***			0.506***	0.506***			0.507***	0.507***
			(0.0449)	(0.0636)			(0.0447)	(0.0642)			(0.0462)	(0.0644)
lnirrigation			0.0923***	0.0923***			0.099***	0.099***			0.099***	0.099***
			(0.0201)	(0.0291)			(0.0193)	(0.0301)			(0.0189)	(0.0301)
oilprice			-0.0390	-0.0390			-0.0446	-0.0446			-0.0464	-0.0464
			(0.0836)	(0.0622)			(0.0797)	(0.0705)			(0.0838)	(0.0674)
Crisis			-0.110	-0.110			-0.127	-0.127			-0.128	-0.128
			(0.106)	(0.0752)			(0.119)	(0.0810)			(0.122)	(0.0838)
Constant	2.199***	2.199***	-0.159	-0.159	2.062***	2.062***	-0.154	-0.154	2.001***	2.001***	-0.162	-0.162
	(0.0864)	(0.463)	(0.281)	(0.371)	(0.0522)	(0.0555)	(0.225)	(0.294)	(0.006)	(0.0485)	(0.229)	(0.298)
Estimator	Dris-kraay standart errors fixed effect estimator, cross-sectional time-series FGLS regression (AR1, heteroskedastic)											

Table A.3: Robustness – Regression Results for Non-Temperature Climate Variables