DOI Link: https://doi.org/10.61586/jVro9
Vol. 43, Issue.6, Part.1, June 2025, PP. 42-61

THE EFFECTS OF GLOBAL WARMING AND CLIMATE CHANGE ON HAZELNUT PRODUCTION, NUMBER OF FRUITING TREES AND YIELD VALUES IN TÜRKİYE (PANEL DATA ANALYSIS)

Assistant Professor Dr. Kurtuluş MERDAN
Gümüşhane University Vocational School of Social Sciences/Gümüşhane

Received April 2025 Accepted May 2025 Published June 2025

ABSTRACT

In the modern world, the uncontrolled exploitation of natural resources driven by humankind's pursuit of greater dominance over nature and convenience has exacerbated the climate change process that began with the Industrial Revolution. This phenomenon has reached critical levels today. In recent years, the risk and uncertainty caused by climatic events experienced almost throughout the earth's crust due to global warming have started to affect agricultural products and ecosystems more than ever. Each ecological zone experiences these changes to different extents. Notably, in regions characterized by species-specific climatic traits and dominated by monoculture, the effects of these transformations are more pronounced. In this context, examining the impacts of climate change on hazelnut agriculture in Turkey's Black Sea Territory, where hazelnut farming is prevalent, and analyzing the outcomes are of great importance.
This study aimed to examine the effects of climate variables measured monthly between 2004 and 2022 on hazelnut yield, tree count, and productivity across leading hazelnut-producing provinces of Ordu, Samsun, Sakarya, Giresun, Düzce, Trabzon, Zonguldak, Artvin, Kocaeli, Bartın, Bolu, and Rize, including all districts within these provinces, through econometric modeling. To assess current climatic conditions, meteorological station data recorded on minimum, average, and maximum temperatures, precipitation, humidity, and wind were analyzed. These twelve provinces were utilized as the scale of analysis for hazelnut cultivation. The model included a cross-sectional application, where provinces served as individual units, and a time series covering 19 years from 2004 to 2022 was used. The model incorporated hazelnut production volume, the number of fruit-bearing trees, and yield values as dependent variables, while atmospheric pressure, relative humidity, wind, temperature, and precipitation were considered independent variables. Based on the findings obtained in the study, regression models with fixed and random effects (Model-1, Model-2, and Model-3) revealed that atmospheric pressure, relative humidity, temperature, and precipitation variables did not independently have significant effects on hazelnut production volume, the number of productive hazelnut trees, or hazelnut yield.

Keywords: Hazelnut, Climate, Yield, Production Amount

a) INTRODUCTION

Although the global climate appears to have a static structure, it has undergone changes over the years. Climatologists have attributed this transformation to various causes. While some have argued that continental drift and mountain formation have influenced the climate, others have attributed these changes to volcanic eruptions. Another group of climatologists has agreed that alterations in the Sun’s magnetic field have changed the amount of energy reaching the Earth, leading to periods of extreme warming and cooling (Brass, 2002; Şanlı and Özekiçioğlu, 2007; Aguirre, 2017; Abbas et al., 2022). At present, discussions surrounding global climate change predominantly focus on greenhouse gases. Increasing human activity in agriculture, industry, transportation, and energy, particularly the use of fossil fuels, has led to a rise in greenhouse gas emissions into the atmosphere, accompanied by changes in land use, which in turn have intensified the greenhouse effect. It is projected that due to greenhouse gas emissions, temperatures will continue to rise globally and will accelerate further during the twenty-first century (Walter et al., 2002; Oğuz, 2009; Busch, 2011; Waskey, 2012; Vural, 2018; Çapar, 2019).
Along with global warming, the risks and uncertainties caused by climate events occurring across nearly the entire Earth’s crust have begun to affect agricultural activities more than ever before. Considering that agricultural production is largely dependent on natural conditions, it is believed that the changing climate and soil structure will have a multiplier effect, leading to sharp fluctuations in agricultural output and the food industry. This situation, in turn, will adversely impact food prices and inflation. In summary, global warming is a phenomenon that affects not only the agricultural sector and its workers but also the entire society as consumers. Climate change necessitates that producers adapt to new production methods and conditions, while policymakers are compelled to review agricultural policies and implement measures to minimize risks (Deniz and Hiç, 2022, p. 13).
Global warming and climate change affect both the prevailing climate zones and water resources, creating upward pressure on the prices of agricultural and food products due to declines in yield and productivity (Zheng et al., 2014). The prices of agricultural products serve as an important indicator in assessing the impact of climate change on the agricultural sector. In addition, climate change causes price fluctuations in agricultural products and poses an obstacle to central banks’ price stability objectives. Under these circumstances, the Central Bank loses its flexibility in combating inflation (Temur, 2017, p. 56).
In recent years, due to the effects of global warming and climate change, there has been a noticeable decline in agricultural land per capita. This decrease has reached up to 14.3% in developed countries and up to 40% in developing countries. While the current amount of agricultural land per capita stands at 0.23 hectares, it is projected that this figure will decline to 0.15 hectares by 2050 due to climate change. Moreover, it is stated that agricultural production will decline by 50% in regions more severely affected by drought, such as the Middle East and Africa (Filinte, 2007; Bütüner, 2019).

The ongoing process of climate change since the Industrial Revolution has reached serious dimensions today due to excessive degradation of natural resources and humanity's increasing dominance over nature. Research reports that the ecosystem and many agricultural products are being affected by climate change at varying levels. The degree of impact varies by species, and changes are more pronounced in regions characterized by specific climatic features and dominated by monoculture (Cruz, 2007). The adverse effects of climate change have reached levels that threaten both the quantity and yield of hazelnut production.

Although growing hazelnuts is widespread in many countries around the world, the number of countries engaged in hazelnut production on an economically significant scale is limited. In Turkiye, hazelnuts are among the significant traditional agricultural products due to their value-added contribution and their role in employment. Hazelnut production provides foreign currency revenue for Türkiye and constitutes a significant source of income for producers in the Black Sea Region. Initially cultivated only in the eastern provinces of the Black Sea region, hazelnut production has gradually extended westward, significantly expanding production areas (Alkan and Kılıç, 2007). While hazelnuts are produced in 39 provinces in Türkiye, production has become concentrated in recent years, particularly in Ordu, Samsun, Sakarya, Giresun, Düzce, Trabzon, Zonguldak, Artvin, Kocaeli, Bartın, Bolu, and Rize (Kılıç et al., 2020).

While Türkiye ranks first in the world in hazelnut production, it ranks 4th in productivity. This situation can be explained by the high amount of hazelnut production and production areas in Türkiye. To achieve high yields in hazelnut production, appropriate and sufficient implementation of cultural and technical practices is essential; moreover, an in-depth understanding of pollination biology, phenological characteristics, and ecological requirements is necessary. Additionally, as the harvest season progresses, hazelnuts that fall to the ground and remain there for extended periods with damaged shells are prone to rot and mold (Beyhan, 2020). The fundamental principle in hazelnut harvesting is to avoid prolonged exposure of hazelnuts to the ground. Otherwise, mold formation and significant yield losses may occur (Ünal, 2007).

In this study, the impact of global warming and climate change on agricultural products was first addressed conceptually. Subsequently, to develop the methodology, studies in the literature on the effects of climate conditions on perennial crops were examined. The relationship between global warming and the agricultural sector was then discussed. In the implementation section of the study, a panel data analysis was conducted to determine the effect of global warming and climate change on hazelnut yield. At the end of the study, it was revealed that climate change adversely affects the production quantity and yield of hazelnuts. This study identified how hazelnuts, a strategic crop, have changed over the years in terms of cultivated area and number of trees within the process of climate change. Due to the lack of a long-term study presenting the spatial and temporal distribution of hazelnut yield and the effects of average humidity, temperature, pressure, wind, and precipitation conditions on this distribution, the present research is expected to fill an important gap in the literature.

b) RELATED LITERATURE

In recent decades, global and regional climates have experienced drought and desertification, along with both observed and unpredictable climatic changes. Temperatures are rising, some areas are experiencing extreme precipitation and drought, and extreme weather events are occurring. The effects of global warming and weather extremes, especially on urban, industrial, and agricultural areas, have been examined in many publications, particularly in the reports of the IPCC. These impacts extend to a wide range of fields, including the economy, livestock, tourism, forestry, and human health, and continue to be studied. It is expected that the impacts of climate change on humans and the environment will grow in the future. Numerous studies at local, national, and global levels have examined the effects of climate change on agricultural activities for different products (Thompson, 1986; Stooksbury and Michaels, 1994; Kaufmann and Snell, 1997; Perkey and Hayes, 1998; Freckleton et al., 1999; Gadgil et al., 1999; Aleksandrov and Hoogenboom, 2000; 2001; Pienkowski and Beaufoy, 2002; Motha and Baier, 2005; Luedeling et al., 2011; Wainwright et al., 2014; Pope et al., 2015; Banias et al., 2017; Bisbis et al., 2018; Mir and Kottaiveeran, 2018). A review of the literature shows that most of the studies focus on the effects of climate conditions on annual field crops. However, there are not many studies on perennial orchard crops, which include the subject of this research. Since hazelnut is a perennial crop, this study is expected to contribute to the literature in terms of both content and methodology.

To develop the methodology used in this study, research on the effects of climate conditions on perennial crops in the literature was examined.

Carbone and Schwartz (1993) conducted a study on how climate change affects peach production, which is a perennial crop. In their study, they adopted South Carolina as the scale. Based on their findings, a 2 °C increase in winter temperatures did not significantly affect production, as the chilling requirements of the peach trees remained within the threshold values. However, when the temperature increased by 4 °C in winter, the chilling requirements fell below the threshold throughout the region, negatively impacting production. In the evaluation section of the study, they recommend breeding new varieties with lower chilling requirements.

Chmielewski et al. (2004) based their study on perennial crops over the period 1961–2000. They examined the effects of observed temperature changes on the development of fruit trees. They concluded that temperature changes did not significantly affect plant development and, consequently, did not greatly affect productivity.

Lobell et al. (2006) investigated the potential impact of future climate change on perennial crops such as wine grapes, almonds, oranges, walnuts, avocados, and table grapes at the scale of California. In the study, crop productivity was tested based on changes in temperature and precipitation. The results of the study revealed a high variation in the yield values of the five crops, except wine grapes. The study also emphasized that the statistical methods used can produce strong and reliable forecasts for the future.

Lobell and Kimberly (2007) examined the effects of temperature values and total precipitation on the productivity of perennial crops. In their California-based study, they developed a regression-based statistical model using data from 1980–2003. When analyzing the resulting model, they found that it explained more than 50% of the variation in productivity across all products. Since the data were obtained as monthly averages, the effects of extreme values on productivity were not calculated.

Ustaoğlu (2009) examined the possible effects of climate change on hazelnut agriculture in Türkiye. The study focused on Kocaeli, Sakarya, Düzce, Samsun, Ordu, Giresun, and Trabzon provinces. The data included hazelnut planted area (ha), production quantity (tons), and productivity (tons/ha), and meteorological variables including minimum, average, and maximum temperatures, precipitation, humidity, and wind, all obtained from meteorological stations. The common study period was 1993–2007. The findings indicated that temperature was the most critical climate factor in hazelnut cultivation.

Aydın and Kızılaslan (2010) examined the effects of global warming on fig production in the Nazilli district of Aydın province. Their study found significant regional changes in temperature and precipitation. As a result, it was concluded that instability in the rainfall regime negatively affected fig production, while rising temperatures caused figs to ripen earlier.

Akçin (2010) studied the factors affecting hazelnut yield in the Gülyalı district of Ordu. In the study, the Palaz, Kara, Sivri, Kus, and Tombul varieties were used as samples. Pomological characteristics, phenological observations, and yield traits were determined. According to the variance analysis conducted, all traits except for the number of shriveled nuts and total bud count showed significant differences depending on the variety.

Şahin et al. (2015) examined the effects of sudden temperature changes on perennial plants within the context of Türkiye. Their findings indicate that, in recent years, fruit trees have increasingly been exposed to abrupt temperature drops during the flowering period, which has adversely impacted both fruit yield and quality. The study also reports that pollinator bees have been negatively affected by these climatic anomalies.

In a nationwide study in Türkiye, Çakmak (2016) investigated the impact of global warming on citrus cultivation, a significant category among perennial crops. Based on the findings, it is anticipated that rising global temperatures will enable citrus farming to extend into the inner regions of Anatolia, allow for the harvesting of a second crop in a single season in these inland areas, and support the cultivation of tropical crops along the Mediterranean coast.

According to the existing literature, studies examining the relationship between annual hazelnut yield and climatic conditions in Türkiye have primarily focused on a limited number of provinces. These studies have been conducted to reveal the effects of changes in temperature and precipitation on hazelnut productivity (Ustaoğlu, 2012; Ustaoğlu & Karaca, 2014; Coşkun & Sözen, 2017; Bütüner, 2019; An et al., 2020; İrdem, 2021, p. 244).

A prevalent conclusion across these studies is that global warming and climate change exert negative effects on hazelnut yield, the number of fruit-bearing trees, and overall productivity. Local administrators, however, appear to fall short in responding to these challenges and have yet to develop effective adaptation strategies. Consequently, it is widely expected that climate change will result in increasingly frequent and large-scale difficulties for agricultural producers in the future.

c) THE RELATIONSHIP BETWEEN GLOBAL CLIMATE CHANGE AND THE AGRICULTURAL SECTOR

Agriculture and climate are inherently interconnected. Greenhouse gases emitted as a result of agricultural practices contribute to climate change, which in turn adversely affects all sectors of the economy, with agriculture being vulnerable to climate change (Abid et al., 2015).

Beginning in the late 1950s, the widespread adoption of irrigation, intensive use of fertilizers and pesticides, and the rise of capital-intensive farming practices led to continuous increases in agricultural output. However, by the 1970s, the persistent misuse of agricultural methods gave rise to numerous environmental problems. Issues such as groundwater contamination, declining soil fertility, and soil erosion prompted a critical reassessment of agricultural techniques and necessitated the development of more environmentally sustainable policies. As a result, greater emphasis was placed on agricultural research, and the importance of sustainable production systems gained prominence. By the 1980s, problems such as the unregulated and excessive use of agricultural chemicals led to a rapid increase in greenhouse gas emissions. When compounded by global warming, these emissions made climate change inevitable. Climate change affects the agriculture sector and the food demand with the growing world population. Decreases in agricultural productivity and the loss of arable land present serious challenges to feeding an expanding global population, raising increasing concern among scientific communities. The ongoing changes in climate change and its negative effects are becoming more destructive for the rural poor engaged in agriculture. In recent years, the increased frequency of extreme weather events,

such as floods, droughts, storms, frosts, and erratic precipitation patterns, has negatively affected crop quality and yield. Changes in temperature, precipitation, and soil moisture levels disrupt the physiological structure of plants, contributing to the proliferation of agricultural pests and a rise in foodborne diseases. Despite advances in irrigation and food technologies, climatic factors such as precipitation, humidity, and temperature remain critical to agricultural production. Moreover, various additional elements shape agricultural output, including technological capacity, access to water resources, soil fertility and quality, policy incentives, tax and tariff regimes, administrative practices, land use regulations, pests, and diseases (Kurukulasuriya & Rosenthal, 2003: 3; Akalın, 2014, p. 357).
Global climate change also alters the diversity of agricultural crops. This shift leads to reduced productivity and places stress on global food production (McMichael & Githeko, 2007, p. 473). Changes in precipitation patterns due to climate change are expected to significantly affect crop variety and yield. Irregular precipitation patterns could disproportionately disadvantage the southern latitudes, where many developing countries are located, compared to the northern latitudes. Rice and wheat, which are classified as temperate zone plants that require low temperatures and high carbon dioxide concentrations and have a low ability to utilize light intensity, are expected to benefit from the increased levels of carbon dioxide. On the other hand, C4 plants such as corn and sugarcane, which are primarily grown in African and Latin American countries, require high temperatures, low carbon dioxide concentrations, and lower amounts of water, are resistant to seasonal droughts and bind organic molecules that initially contain 4 carbon atoms, and they have a high ability to utilize light intensity; however, they are expected to be negatively affected by the increased levels of carbon dioxide ((Doğan & Tüzer, 2011, p. 30; Akalın, 2014, p. 358; Zheng et al., 2020).

Global climate change has also triggered significant transformations in climate parameters. It is considered a primary driver behind diminishing water volumes and declining water quality, drought, glacial and snow melt, alterations in the hydrological cycle, increased frequency of meteorological disasters, wildfires, and shifting precipitation regimes. Beyond its physical effects, climate change also entails socio-economic and political consequences. Chief among these are rising migration, increased risks for coastal settlements, energy shortages, reductions in agricultural and forest production, and constraints on tourism opportunities (Babuş, 2005; Türkeş, 2007; Dündar, 2007; Bütüner, 2019).

d) MATERIALS AND METHODS

Panel data can be categorized as balanced or unbalanced depending on the status of the observations for the variables. A balanced panel refers to the situation where cross-sectional observations are available across all- time series, while an unbalanced panel occurs when the observations vary across the units in the panel (Gujarati, 2004, p. 640). In this study, since the annual data covering the 19-year period from 2004 to 2022 for 12 provinces was complete, the analyses were carried out using a balanced panel. The factors affecting the dependent variables, including hazelnut cultivation area, number of fruit-bearing hazelnut trees, and hazelnut yield, were examined in three separate models. In all three models, the independent variables included atmospheric pressure, relative humidity, wind, temperature, and precipitation. To test the models, regression analysis was conducted using the Driscoll-Kraay estimator. Prior to the analysis, normal distribution (Jarque- Bera), cross-sectional dependence, homoscedasticity, autocorrelation, and unit root tests were applied to the variables. Table 1 provides statistical descriptions of the variables included in the research models.

Table 1. Descriptive statistics of variables included in the models

	Abbreviation	Min.	Max.	Mean	SD	J-B (p)
Pressure	PRS	992.60	1017.20	1008.99	7.18	4.25 (0.119)[1]
Relative Humidity	HMD	57.70	90.20	73.41	6.05	2.56(0.277)
Wind	WD	0.52	2.97	1.56	0.45	4.92(0.085)
Temperature	TEMTR	11.50	17.00	14.78	1.14	5.23(0.073)
Precipitation	PRECT	407.80	2523.40	1028.58	421.46	4.81(0.090) [1]
Production Quantity	PRQANT	47	239935	4812.6	51646.6	5.83(0.055) [1]
Number of Fruit-Bearing Hazelnut Trees	HZNTTRE	42	142817	29302.93	34692.6	4.12(0.127) [1]
Yield	YİD	9.80	200.40	88.51	38.97	5.57(0.061)

The Jarque-Bera (1987) test examines whether the data follow a normal distribution. The null hypothesis (H0) of this test states that the data are normally distributed. To determine whether the data are normally distributed in the Jarque-Bera test, p-values are analyzed. Logarithmic transformations were applied to make the series conform to a normal distribution.

As with traditional regression models, stationarity is a prerequisite in panel regression analyses as well. In panel data analysis, unit root tests of the first or second generation are applied for determining the stationarity of series, depending on whether there is cross-sectional dependence. Second-generation unit root tests take into account the correlation among cross-sectional units. While second-generation panel unit root tests model the correlation among units as low-dimensional factors, this study includes 12 cross-sectional units (12 provinces) and 19 periods (annual data between 2004 and 2022). Since T (19) > N (12) in this case, the Breusch & Pagan LM test (1980) is more appropriate for testing cross-sectional dependence. The null hypothesis (H0) of the Breusch & Pagan LM test (1980) is that “there is no cross-sectional dependence among the series.” If $p < 0.05$, the null hypothesis is rejected, indicating cross-sectional dependence among the series. The null hypothesis to be tested is as follows:

$H_0 = H_o$ = There is no dependence between the cross-sections (H_0 $p_{ij} = 0$; for all $i \neq j$)

Table 2. Cross-sectional dependence results

Series	df	Breusch-Pagan LM	Peseran Scaled LM	Bias-Corrected Scaled LM	Pesaran CD
Pressure	66	466.71*	33.83*	33.50*	17.84*
Relative Humidity	66	130.43**	4.56**	4.23**	4.08**
Wind	66	252.11**	15.15**	14.82**	5.86**
Temperature	66	805.20**	63.29**	62.96**	25.70**
Precipitation	66	159.22**	7.07**	6.73**	8.92**
Number of Trees	66	243.79**	14.43**	14.09**	4.38**
Cultivation Area	66	333.18**	22.21**	21.88**	3.59**
Production Quantity	66	205.10**	11.06**	10.73**	10.57**
Yield	66	167.96**	7.83**	7.50**	8.44**

*p<0.05 **p<0.01

According to the cross-sectional dependence results in Table 2, the p-values of the Breusch-Pagan LM (1980) test statistic are statistically significant at the 0.01 level for each variable. This indicates that the null hypothesis of "no dependence between cross-sections" is rejected, and cross-sectional dependence is present. Since cross- sectional dependence was identified, second-generation unit root tests, specifically, the CIPS (Cross- sectionally Augmented IPS) and Cross-sectionally Augmented ADF (Pesaran, 2007) tests, were used for the stationarity test. In both tests, the null hypothesis (H0) indicates the presence of a unit root; if p<0.05, it implies the absence of a unit root, and that the series are stationary. When a series contains a unit root, its mean must be rendered stationary by taking the first- or second-order differences. Unit root test results are presented in Table 3.

Table 3. Unit root (stationarity) test results

Series	Pesaran CADF		Pesaran CIPS	
	Level I(0) *I*(0)	**1st Diff. *I*(1)**	**Level I(0) *I*(0)**	**1st Diff. *I*(1)**
Pressure	-2.919**		-2.609**	
Relative Humidity	-0.281	-6.065**	-1.833	-3.536**
Wind	-4.281**		-3.010**	
Temperature	-0.658	-9.683**	-1.944	-4.601**
Precipitation	-5.347**		-3.324**	
Production Quantity (Ton)	-6.673**		-3.715**	
Number of Fruit-Bearing Trees	-1.481	-8.433**	-2.186	-4.233**
Yield (kg/da)	-7.276**		-3.892**	

*p<0.05 **p<0.01

According to the unit root test results in Table 3, the variables pressure, wind, precipitation, production quantity, and yield are stationary at level, while relative humidity, temperature, and the number of fruit-bearing trees are not stationary at level but become stationary upon taking the first differences.

Panel data analysis in the classical model is applied in the form of fixed effects and random effects models. The selection of which of these estimation methods to use is determined by the results of relevant tests. The Hausman test was used to determine whether to apply the fixed or random effects model. The Hausman test is used to assess whether the difference in parameter estimators is statistically significant between the fixed and random effects models (Baltagi, 2014).

H0: The difference between parameters is not systematic (random/coincidental)

H1: The difference between parameters is systematic (not random/not coincidental)

Rejection of the null hypothesis indicates that the fixed effects model will be used.

Table 4. Hausman test for model selection

Model	X^2	df	p	Appropriate Model
Model 1 (Dependent variable: Production quantity)	2.68	5	0.749	Random effects model
Model 2 (Dependent variable: Number of fruit-bearing trees)	0.28	5	0.998	Random effects model
Model 3 (Dependent variable: Yield)	4.36	5	0.499	Random effects model

df: Degree of freedom

As shown in Table 4, the result of the Hausman test (since the p-value of the X^2 test was > 0.05, the null hypothesis H0 was accepted) indicated that the random effects model was appropriate.

The heteroscedasticity problem suggests that the covariance of the error terms across cross-sections is not equal to zero; in other words, the variances are not constant and exhibit variability. Since heteroscedasticity leads to inaccurate results in panel regression, the methods to be applied are determined based on its presence. In the White (1980) test conducted for this purpose, the null hypothesis is that of homoscedasticity. The Breusch- Pagan (1979) test also assumes the null hypothesis that variances are constant. If the p-value associated with the calculated X^2 statistic is less than 0.05 in either test, it is concluded that heteroscedasticity is present. It is important to note some limitations of the White test: it may have low power when the sample size is small or when there are many explanatory variables (Gujarati, 2004). Table 5 presents the results of the White and Breusch-Pagan tests.

Table 5. Heteroscedasticity test results

Model	Test	X^2	df	p
Model 1 (Production quantity)	White	72.79	20	0.000
	B-P	0.47	1	0.495
Model 2 (Number of fruit-bearing trees)		28.45	20	0.099
		33.00	1	0.000
Model 3 (Yield)		30.91	20	0.056
		3.77	1	0.052

df: Degrees of freedom B-P: Breusch-Pagan

According to the White test in Table 5 ($p < 0.05$ for the X^2 statistic), it was found that heteroscedasticity is present in Model 1, but not in Models 2 and 3. On the other hand, according to the Breusch-Pagan test ($p < 0.05$ for the X^2 statistic), heteroscedasticity is present in Model 2, but not in Models 1 and 3. Since the Breusch- Pagan test may produce biased results when errors are not normally distributed or when nonlinear forms are involved (Williams, 2020), the fixed effects model was considered for Model 3 (where both tests indicate no heteroscedasticity), while random effects models were used for Models 1 and 2.
The autocorrelation problem refers to the existence of a significant relationship between successive values of the error terms. This indicates that the error terms are not independent from each other, which leads to a systematic relationship among error terms in panel data analysis and results in biased regression outcomes. The Baltagi and Li test statistic was used to test for autocorrelation. Baltagi and Li (1991) recommended that the LM test be used to detect serial correlation under the assumption of normally distributed and homoscedastic error terms in the random effects model. Autocorrelation in residuals can influence random effects, and the presence of random effects can, in turn, lead to autocorrelated residuals. Therefore, the application of a joint test emerges as a solution. This test is a simple LM test that simultaneously examines random effects and autocorrelation and is considered an extension of the Breusch-Pagan LM test (Baltagi and Li, 1991). Table 6 presents the autocorrelation test results.

Table 6. Baltagi and Li Joint Autocorrelation Test Results

Model	X^2	df	p
Model 1 (Production quantity)	1494.29	2	0.000
Model 2 (Number of fruit-bearing trees)	7.86	2	0.019
Model 3 (Yield)	25.00	2	0.000

According to the Baltagi and Li joint autocorrelation test results in Table 6, since the p-values for the X^2 statistic were < 0.05 for all three models, the H0 hypothesis was rejected. In other words, the successive values of the error terms are not independent, indicating the presence of autocorrelation in the models.
To address cross-sectional dependence, heteroscedasticity, and autocorrelation problems in fixed and random effects models, the Driscoll-Kraay (1998) estimator was used. The Driscoll-Kraay standard errors can be applied in the presence of heteroscedasticity, autocorrelation, and cross-sectional dependence (correlation among panels) and do not impose any constraints on the limiting behavior of the number of panels. Table 7 presents the results of the random and fixed effects models used to estimate hazelnut production quantity (Model 1), the number of fruit-bearing trees (Model 2), and yield (Model 3).

Table 7. Estimation of hazelnut production quantity, number of fruit-bearing trees, and yield using the Driscoll-Kraay Estimator and GLS Method

		Random Effects				Fixed Effects			
Research Model	**Independent Variable**	**B**	**SE**	**t**	**p**	**B**	**SE**	**t**	**p**
Model-1 Dependent variable: Production Quantity	Pressure	0.026	0.038	0.70	0.496	0.026	0.043	0.60	0.558
	Relative Humidity	-0.003	0.002	-1.48	0.157	-0.003	0.002	-1.52	0.147
	Wind	-0.182	0.086	-2.12	**0.049**	-0.185	0.097	-1.91	**0.073**
	Temperature	0.005	0.018	0.31	0.763	0.005	0.018	0.29	0.775
	Precipitation	-0.043	0.044	-0.98	0.340	-0.039	0.045	-0.88	0.393
	C	-0.890	0.340	-2.62	0.018	-0.911	0.283	-3.22	0.005
		Wald X^2=28.45 p=0.000 R^2=0.040				F=4.72 p=0.006 R^2=0.064			
Model-2 Dependent variable: Number of fruit-bearing trees	Pressure	345.89	162.97	2.12	**0.049**	-128.35	1009.08	-0.13	0.900
	Relative Humidity	25.69	54.51	0.47	0.643	23.65	54.84	0.43	0.672
	Wind	18.56	293.66	0.06	0.950	167.96	841.23	0.20	0.844
	Temperature	204.88	174.89	1.17	0.250	147.13	214.90	0.68	0.503
	Precipitation	-652.11	647.41	-1.01	0.335	-652.11	562.95	-1.16	0.263
	C	4434.68	2052.07	2.16	0.045	4091.35	4759.40	0.86	0.402
		Wald X^2=11.28 p=.046 R^2=0.014				F=0.48 p=0.789 R^2=0.006			
Model-3 Dependent variable: Yield	Pressure	-6.473	4.313	-1.50	0.152	2.733	9.503	0.29	0.777
	Relative Humidity	-1.408	0.571	-2.47	**0.024**	-1.389	0.574	-2.42	**0.027**
	Wind	-26.11	13.27	-1.97	**0.066**	-34.63	18.83	-1.84	**0.083**
	Temperature	0.982	2.983	0.33	0.746	2.226	3.376	0.66	0.518
	Precipitation	-7.246	10.17	-0.71	0.486	-4.795	9.369	-0.51	0.615
	C	166.55	54.05	3.08	0.007	180.00	50.191	3.59	0.002
		Wald X^2=29.19 p=0.000 R^2=0.062				F=6.30 p=0.002 R^2=0.077			

Note: Results for both random and fixed effects models are presented to allow for comparison.

According to the results of the random effects regression model for Model 1 using the Driscoll-Kraay estimator, the explanatory power of meteorological variables on the variation in hazelnut production quantity was determined to be 4%. The model indicates that a 1% increase in wind speed leads to a 0.18% decrease in hazelnut production quantity (B = -0.182; t = -2.12; $p < 0.05$). The Model-1 random effects regression analysis revealed that pressure, relative humidity, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut production quantity ($p > 0.05$).

According to the results of the fixed effects regression model for Model 1 using the Driscoll-Kraay estimator, the explanatory power of meteorological variables on the variation in hazelnut production quantity was determined to be 6%. The model indicates that a 1% increase in wind speed leads to a 0.18% decrease in hazelnut production quantity ($B = -0.185$; $t = -1.91$; $p < 0.10$). The Model-1 fixed effects regression analysis revealed that pressure, relative humidity, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut production quantity ($p > 0.05$).

According to the results of the random effects regression model for Model 2 using the Driscoll-Kraay estimator, the explanatory power of meteorological variables on the variation in the number of fruit-bearing hazelnut trees was determined to be 1%. The model indicates that a 1% increase in atmospheric pressure leads to a 345% increase in the number of fruit-bearing hazelnut trees ($B = 345.89$; $t = 2.12$; $p < 0.05$). The Model-2 random effects regression analysis revealed that relative humidity, wind, temperature, and precipitation variables each do not have a statistically significant individual effect on the number of fruit-bearing hazelnut trees ($p > 0.05$).

According to the results of the fixed effects regression model of Model-2 conducted with the Driscoll-Kraay estimator, meteorological data do not explain the variation in the number of fruit-bearing hazelnut trees ($F = 0.48$; $p > 0.05$). The Model-2 fixed effects regression analysis revealed that pressure, relative humidity, wind, temperature, and precipitation variables, either individually or jointly, do not have a statistically significant effect on the number of fruit-bearing hazelnut trees ($p > 0.05$).

According to the results of the random effects regression model of Model-3 using the Driscoll-Kraay estimator, the explanatory power of meteorological variables on the variation in hazelnut yield was determined to be 6%. According to the model, a 1% increase in relative humidity leads to a 1.41% decrease in hazelnut yield ($B = -1.408$; $t = -2.47$; $p < 0.05$), and a 1% increase in wind speed results in a 26% decrease in hazelnut yield ($B = -26.11$; $t = -1.97$; $p < 0.10$). The Model-3 random effects regression analysis revealed that pressure, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut yield ($p > 0.05$).

According to the results of the fixed effects regression model of Model-3 using the Driscoll-Kraay estimator, the explanatory power of meteorological variables on the variation in hazelnut yield was determined to be approximately 8%. According to the model, a 1% increase in relative humidity leads to a 1.39% decrease in hazelnut yield ($B = -1.389$; $t = -2.42$; $p < 0.05$), and a 1% increase in wind speed results in a 34.6% decrease in hazelnut yield ($B = -34.63$; $t = -1.84$; $p < 0.10$). The Model-3 fixed effects regression analysis revealed that pressure, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut yield ($p > 0.05$).

e) CONCLUSION AND EVALUATION

Global warming and climate change cause drought, water shortages, disruption of the hydrological cycle, an increase in meteorological disasters, excessive sea level rise, a decrease in the quality and quantity of water resources, extreme evaporation, and changes in the amount and regime of precipitation. In addition to the physical effects of global warming and climate change, there are also social and economic impacts, such as a decrease in agricultural products, increased migration, energy bottlenecks, and limitations on tourism opportunities. Underdeveloped and developing countries, lacking the resources to cope with these problems, constantly face crises. All these negative developments reveal the socio-economic significance of climate change.

In this study, which aimed to determine the effects of global warming and climate change on hazelnut production quantity, the number of fruit-bearing trees, and yield values, panel data analysis was employed. The analyses were conducted using a balanced panel based on annual periods for the years 2004–2022, covering 12 provinces. The factors affecting the dependent variables, including hazelnut cultivation area, number of fruit-bearing hazelnut trees, and hazelnut yield, were examined in three separate models. In all three models, the independent variables included atmospheric pressure, relative humidity, wind, temperature, and precipitation. To test the models, regression analysis was conducted using the Driscoll-Kraay estimator. Prior to the analyss, normal distribution (Jarque-Bera), cross-sectional dependence, homoscedasticity, autocorrelation, and unit root tests were applied to the variables. According to the results of the random effects regression model for Model 1, the explanatory power of meteorological variables on the variation in hazelnut production quantity was determined to be 4%. The model indicates that a 1% increase in wind speed leads to a 0.18% decrease in hazelnut production quantity. The Model-1 random effects regression analysis revealed that pressure, relative humidity, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut production quantity. According to the results of the fixed effects regression model for Model 1, the explanatory power of meteorological variables on the variation in hazelnut production quantity was determined to be 6%. This model suggests that a 1% increase in wind speed leads to a 0.18% decrease in hazelnut production quantity. The Model-1 fixed effects regression analysis revealed that pressure, relative humidity, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut production quantity. According to the results of the random effects regression model for Model 2, the explanatory power of meteorological variables on the variation in the number of fruit- bearing hazelnut trees was determined to be 1%. The model indicates that a 1% increase in atmospheric pressure results in a 345% increase in the number of fruit-bearing hazelnut trees. The Model-2 random effects regression analysis revealed that relative humidity, wind, temperature, and precipitation variables each do not have a statistically significant individual effect on the number of fruit-bearing hazelnut trees. According to the results of the fixed effects regression model of Model-2, meteorological data do not explain the variation in the number of fruit-bearing hazelnut trees. The Model-2 fixed effects regression analysis revealed that pressure, relative humidity, wind, temperature, and precipitation variables, either individually or jointly, do not have a statistically significant effect on the number of fruit-bearing hazelnut trees. According to the results of the random effects regression model of Model-3, the explanatory power of meteorological variables on the variation in hazelnut yield was determined to be 6%. The model suggests that a 1% increase in relative humidity leads to a 1.41% decrease in hazelnut yield, while a 1% increase in wind speed results in a 26% decrease in hazelnut yield. The Model-3 random effects regression analysis revealed that pressure, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut yield. According to the results of the fixed effects regression model of Model-3, the explanatory power of meteorological variables on the variation in hazelnut yield was determined to be approximately 8%. The model indicates that a 1% increase in relative humidity results in a 1.39% decrease in hazelnut yield, while a 1% increase in wind speed leads to a 34.6% decrease in hazelnut yield. The Model-3 fixed effects regression analysis revealed that pressure, temperature, and precipitation variables each do not have a statistically significant individual effect on hazelnut yield. Based on the findings obtained, it was concluded that a 1% increase in each unit of temperature, wind, relative humidity, and precipitation leads to a decrease in hazelnut production quantity, number of fruit-bearing hazelnut trees, and yield, while a 1% increase in atmospheric pressure leads to an increase in the number of fruit-bearing hazelnut trees. The results obtained in this study are consistent with the findings of Coşkun and Sözen (2017) and İrdem (2021).

Considering the findings of this study and the literature review, it is expected that in the short term, the average effect of climate change will be negative. The increasing frequency of extreme climate events such as floods and droughts caused by global warming and climate change is adversely affecting agricultural production. To mitigate these negative effects, new agricultural technologies should be developed, and advanced agricultural practices should be further improved.

With this study, considering the importance of hazelnut production for the Turkish economy and the impact of climate on hazelnuts, as well as the emphasis placed on precipitation and temperature in area-based studies regarding hazelnut production, it is believed that examining the temporal and spatial variations in hazelnut yield and identifying the effects of temperature, humidity, and precipitation conditions on yield will fill a significant gap in the literature.

f) REFERENCES

Abbass K, Qasim M Z, Song H, Murshed M, Mahmood H & Younis I (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research,* 29(28): 42539-42559.

Abid M, Scheffran J, Schneider U A & Ashfaq M (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics, 6*(1): 225.

Aguirre A A (2017). Changing patterns of emerging zoonotic diseases in wildlife, domestic animals, and humans linked to biodiversity loss and globalization. *Institute for Laboratory Animal Research Journal*, 58(3): 315-318. https://doi.org/10.1093/ilar/ilx035

Akalın M (2015). Impacts of climate change on agriculture: adaptation and mitigation strategies to address these impacts. *Hitit University Journal of Institute of Social Sciences, 7*(2): 351-378. https://doi.org/10.17218/husbed.87012

Akçin Y (2010). Hazelnut yield and relationships between some traits affecting yield (Unpublished Master's Thesis). Ordu University Institute of Science and Technology, Ordu. 58s.

Alexandrov V & Hoogenboom G (2000). The impact of climate variability and change on crop yield in Bulgaria. *Agric For Meteorology*, 104: 315 327.

Alexandrov V & Hoogenboom G (2001). Climate variations and agricultural crop production in Georgia, USA. *Clim Res*, 17: 33-43.

Alkan I & Kılıç O (2007). Comparative economic analysis of hazelnut enterprises in lowland and upland areas of Terme district of Samsun province. Anatolian Journal of Agricultural Sciences, 22(2): 171-178.

An N, Turp M T, Türkeş M & Kurnaz M L (2020). Mid-term ımpact of climate change on hazelnut yield. *Agriculture*, (10) 159: 1-20. doi:10.3390/agriculture10050159.

Aydın O & Kızılaslan H (2010). The effects of global warming on fig production in Nazilli district of Aydın province. Türkiye IXth Agricultural Economics Congress. Sanliurfa, Türkiye.

Babuş D (2005). Global warming problem in international environmental policy and Turkey's place (Unpublished Master's Thesis), Çukurova University Institute of Science and Technology, Peyzaj Mimarlığı ABD, 212s. Adana.

Banias G, Achillas C, Vlachokostas C, Moussiopoulos N & Stefanou M (2017). Environmental impacts in the life cycle of olive oil: a literature review. *Journal of the Science of Food and Agriculture*, 97(6): 1686 1697. Baltagi B & Li Q (1991). A joint test for serial correlation and random individual effects. *Statistics & Probability Letters. 11*(3): 277-280.

Baltagi B H (2014). Panel data and difference-in-differences estimation. *Encyclopedia of Health Economics.* 425-433. https://doi.org/10.1016/B978-0-12-375678-7.00720-3.

Beyhan N (2000). Effects of different harvest times on some fruit characteristics of hazelnut. Journal of Ondokuz Mayıs University Faculty of Agriculture, 15(3): 1-6.

Bisbis M B, Gruda N & Blanke M (2018). Potential impacts of climate change on vegetable production and product quality–A review. *Journal of Cleaner Production*, 170(1): 1602-1620.

Busch T (2011). Organizational Adaptation to Disruptions in the Natural Environment: The Case of Climate Change. *Scandinavian Journal of Management*, 27(4): 389-404.

Bütüner M (2019). The Effect of Global Climate Change on Hazelnut and Tea Agriculture (Unpublished Master's Thesis), Atatürk University Graduate School of Natural and Applied Sciences, Department of Horticulture, Erzurum, 54s.

Brass G W (2002). Arctic Ocean climate change. US Arctic Research Commission Special Publication No.
02-1, Arlington, VA, 14p.

Breusch T & Pagan A (1980). The Lagrange multiplier test and its application to model specification in econometrics. *Review of Economic Studies,* 47: 239-253.

Breusch T S & Pagan A R (1979). A simple test for heteroskedasticity and random coefficient variation.
Econometrica. 47(5): 1287-1294.

Carbone G J & Schwartz M D (1993). The potential ımpact of winter temperature ıncreases on South Carolina peach production. *Clim Res, 2* (3): 225-233.

Chmielewski F M, Müller A & Bruns E (2004). Climate changes and trends in phenology of fruit trees and field crops in Germany, 1961–2000. *Agric. For. Meteorol.*, 121: 69–78.

Cruz R V (2007). Asia climate change ımpact, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, s. 469-506.

Çakmak B (2016) Global climate change and its impact on water use in agriculture. Environment Foundation of Türkiye Publications, 197-227. Ankara.

Çapar G (2019). Climate change training modules series 8 - supporting joint efforts on climate change project
- Republic of Turkey Ministry of Environment and Urbanization General Directorate of Environmental Management Water Resources Management and Climate Change - Ankara.

Coşkun M & Sözen E (2017). The evaluation of the agriculture of hazelnut in düzce accordıng to climate parameters. *International Journal of Sustainable Agricultural Research, 4* (1): 16-27. doi: 10.18488/journal.70/2017.4.1/70.1.16.27

Deniz M & Hiç Ö (2022). Climate change and the changing face of agriculture: policy recommendations after increasing risks, contractions in agriculture and forest fires. *Journal of Biga Faculty of Economics and Administrative Sciences*, 3(1): 12-22.

Doğan S & Tüzer M (2011). Global climate change and its potential impacts. *Cumhuriyet University Journal of Economics and Administrative Sciences*, 12(1): 21-34.
Dündar M (2007). Su Kaynaklarının Uluslararası Sorun Oluşturması (Unpublished Master's Thesis), Karadeniz Technical University Institute of Social Sciences, International Relations Program, Trabzon, 157 pp.Driscol, J.C. and Kraay, A.C. 1998. Consistent covariance matrix estimation with spatially dependent panel data.
Review of Economics and Statistics, 80, 549-560.
Filinte H M (2007). The coming global climate crisis, Yeni İnsan Publishing House, Istanbul, September.
Freckleton R P, Watkinson A R, Webb D J & Thomas T H (1999). Yield of sugar beet in relation to weather and nutrients. *Agric For Meteorol* 93(1): 39–51.
Gadgil S, Rao P R S & Sridhar S (1999). Modeling impact of climate variability on rainfed groundnut. *Curr Sci* 76(4): 557–569.
Gujarati D N (2004). Basic Econometrics. 4th Edition. NY: McGraw-Hill Companies.
İrdem C (2021). Effects of temperature and precipitation on hazelnut yield in Turkey, *Turkish Journal of Geographical Sciences*, *19*(1): 242-262, doi: 10.33688/aucbd.878206.
Jarque C M & Bera A K (1987). A test for normality of observations and regression residuals. *International Statistical Review*, 55: 163-172.
Robert K K & Seth E S (1997). A Biophysical Model of Corn Yield: Integrating Climatic and Social Determinants. *American Journal of Agricultural Economics, Agricultural and Applied Economics Association*, 79(1): 178-190.
Kılıç O, Aydın E G & Boz İ (2020). Women's labor force participation in hazelnut farming enterprises and its effect on business decisions: The case of Samsun province, Turkish Journal of Agricultural Research, 7(2): 150-155.
Kurukulasuriya P & Shane R (2003). Climate change and agriculture a review of ımpacts and adaptations, The World Bank Envıronment De partment June.
Lobell D & Kimberly C (2007). Historical effects of temperature and precipitation on California crop yields.
Climatic Change, 81 (2):187- 203.
Lobell D, Field C, Kimberly C & Bonfils C (2006). Impacts of future climate change on California perennial crop yields. *Agricultural and Forest Meteorology, 141* (2-4): 208-218.
Luedeling E, Girvetz E H, Semenov M A & Brown P H (2011). Climate change affects winter chill for temperate fruit and nut trees. *PloS one*, 6(5): e20155.
Mir Z A & Kottaiveeran K (2018). Impact of climate changes with special reference to walnut production in Jammu and Kashmir. *International journal of social science and economic research*, 3(2): 608-617.
Motha R & Baier W (2005). Impacts of present and future climate variability on agriculture and forestery in the temperate regions: North america.

Climatic Change, 70: 137–164.
Oğuz C U (2009). İklim Değişikliğinin Ekolojik Bir Süreç Olarak Küresel Ölçekte İrdelenmesi (Unpublished Doctoral Dissertation). Akdeniz University Institute of Social Sciences, Antalya.

Perkey D J & Hayes C E (1998). Alabama corn and cotton production and its relation to precipitation. Proceedings of the 23rd Conference on Agricultural and Forest Meteorology, Albuquerque, NM. American Society of Meteorology, Boston, MA, p 90–93.

Pesaran M H (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265-312.

Pienkowski, M & Beaufoy G (2002). The environmental impact of olive oil production in the European Union: practical options for improving the environmental impact. In European Forum on Nature Conservation and Pastoralism.

Pope K S, Dose V, Da Silva D, Brown P H & DeJong T M (2015). Nut crop yield records show that budbreak- based chilling requirements may not reflect yield decline chill thresholds. *International journal of biometeorology*, 59(6): 707-715.

Stooksbury D E & Michaels P J (1994). Climate change and large area corn yield in the Southeastern United States. *Agron. J.*, 86: 564-569

Sahin M, Topal E, Ozsoy N & Altunoglu E (2015). Effects of climate change on fruit growing and beekeeping.
Anatolian Journal of Natural Sciences, 6(Special Issue 2): 147-154.

Şanlı B & Özekicioğlu H (2007). Efforts to prevent global warming and Turkey. *Karamanoğlu Mehmetbey University Journal of Social and Economic Research*, 2: 456-482.

Temur B (2017). The ımpact of global warming on agriculture sector in Turkey: An ARDL model application. (Unpublished Master's Thesis) Anadolu University Institute of Social Sciences, Eskişehir.

Türkes M (2007). What is Global Climate Change? Basic Concepts, Causes, Observed and Projected Changes,
I. Turkey Climate Change Congress-TİKDEK, ITU, Istanbul.Thompson, S N (1986). Nutrition and In Vitro culture of insect parasitoids. *Ann. Rev. Entomol.*,31: 197-219.

Ustaoglu B (2012). The Effect of Climatic Conditions on Hazelnut (Corylus Avellana) Yield in Giresun (Turkey). Marmara Journal of Geography, (26): 302-323. Retrieved from https://dergipark.org.tr/tr/pub/marucog/issue/473/3888 on 09.11.2020.

Ustaoğlu B & Karaca M (2014). The Effects of climate change on spatiotemporal changes of hazelnut (corylus avellana) cultivation areas in the Black Sea Region, Turkey. *Applıed Ecology and Environmental Research*, *12* (2): 309-324. doi: 10.15666/aeer/1202_309324.

Ustaoglu B (2009). Possible effects of hazelnut change on hazelnut agriculture in Turkey (Unpublished PhD Thesis). Istanbul Technical University Eurasia Institute of Earth Sciences, Istanbul.

Ünal A (2007). Modern Hazelnut Agriculture, Akçakoca, 231 p.

Vural Ç (2018). Global climate change and security. Journal of Security Sciences, 7 (1): 57-85.
Wainwright H, Jordan C & Day H (2014). Environmental impact of production horticulture. In Horticulture: Plants for People and Places, Volume 1. Dordrecht : Springer. 503-522.
Walther G R E, Post P, Convey A, Menzel C, Parmesan R J C, Beebee J M, Fromentin O, Hoegh-Guldberg F B (2002). Ecological responses to recent climate change. *Nature*, 416: 389-395.
Waskey A J (2012). Global warming. In S. G. Philander (Ed.), Encyclopedia of global warming and climate change (pp. 640-645). SAGE.
White H (1980.) A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica. 48(*4): 817-838.
Williams R (2020). Heteroskedasticity, http://www3.nd.edu/~rwilliam/stats2/l25.pdf (Erişim Tarihi: 18.09.2024).
Zheng M, Meng Y, Yang C, Zhou Z, Wang, Y & Chen B (2014). Protein expression changes during cotton fiber elongation in response to drought stress and recovery. Proteomics, 14: 1776–1795.
Zheng H, Liu Y, Chen Y, Zhang J, Li H & Wang L (2020). Short term warming shifts microbial nutrient limitation without changing the bacterial community structure in an alpine timberline of the eastern Tibetan plateau. Geoderma. 360, 113985.