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The effect of precipitation and temperature on wheat yield in Turkey: a panel FMOLS and panel VECM approach

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Abstract
Wheat is one of the products that can have the greatest effect of climate anomalies. Turkey is among the top 10 countries in the world with the production of approximately 20 million tons of wheat per year. In this study, the effect of the changes in temperature and precipitation in Turkey between 1997 and 2016 on wheat yield was investigated by panel FMOLS and panel VECM analysis. The study includes three regions that slight drought, moderate drought and severe drought. According to the analysis results, in each of the three regions evaluated, it appears that yield is inversely related to temperature, while there is a positive relationship with precipitation. As a result of the vector error correction model, in slight drought (SLD), moderate drought (MD) and severe drought regions (SVD), long-term causality relation between temperature and precipitation factors with wheat yield was determined. In conclusion, it can be said that due to climatic trends caused by climatic factors, the 1% increase in temperature may lead to yield loss of 0.84%, 0.43 and 0.48% for wheat in SVD, MD and SLD regions, respectively. Similarly, the 1% increase in precipitation may increase the wheat yield as 0.20%, 0.12 and 0.09% in SVD, MD and SLD regions, respectively. Accordingly, it may be suggested to re-model some practices taking into account the changing climatic conditions such as the selection of appropriate varieties, agricultural production systems and sowing dates.

Keywords Agricultural policy · Precipitation · Panel cointegration–FMOLS–VECM · Temperature · Turkey · Wheat yield

1 Introduction

Agricultural production faces various risks since agricultural production involves a process that depends on natural conditions. Natural phenomena are at the top of these risks. Climatic factors can adversely affect this production process in some periods. For this

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reason, many researchers in the world are making predictions and estimation studies on the effect of climate factors on yield by using plant growth models and statistical techniques (Jones et al. 2017). Because the production process is a difficult process to control, it is important to know the effects in advance and take the necessary precautions. Risks due to natural conditions pose significant concerns to producers. According to the 5th Report of Intergovernmental Panel on Climate Change (IPCC), it is stated that the global average surface temperature increase in the period of 2016–2035 will be between 0.3 and 0.7 °C compared to 1986–2005 period (IPCC 2013). Many countries, including Turkey, are developing policies for climate change to minimize the adverse effects that may arise. These policies are extremely important in terms of the agricultural sector, which will be the most affected by the risks. For this reason, studies are aimed at eliminating the negative consequences of climatic factors and shed light on efforts of ensuring food safety in the future.

Food safety is defined as the ability of all people to have access to adequate, safe and nourishing food at all times to maintain their lives in a healthy and effective manner (World Food Summit 1996). The expectation that the world population will be 10.2 billion in 2050 in the population scenario also makes food safety important. This expectation also makes food safety important (UN 2017). In this scope, wheat production comes to the forefront. Wheat constitutes the main source of the most important basic foodstuffs of human beings (Hokazono and Hayashi 2012; Estes et al. 2013; Lobell et al. 2013; FAO 2017). Therefore, it is considered as a strategic product for many countries. It is also a key product in the establishment of national agricultural policies. Especially the nature of growing in drought areas, the role of flour obtained from wheat and its products in human nutrition demonstrates why wheat is a very important strategic product.

Turkey is a suitable country for wheat farming from the point of both its climatic structure and its culture. When the statistical data of the institutions such as TURKSTAT (Turkish Statistical Institute) and FAO (Food and Agricultural Organization) are examined, Turkey's annual wheat production is about 20 million tons. The value of said production is about $ 5–7 billion (FAOSTAT 2017; TURKSTAT 2017). While wheat agriculture in Turkey is mostly produced in summer in the coastal regions of Thrace, Mediterranean, Aegean and Marmara, it is mostly produced in winter in other regions (Kan et al. 2017). Turkey's wheat yield is around 2620 kg/ha (FAOSTAT 2017). From the perspective of its added value, it can be said that the agricultural industry based on wheat and wheat products is one of the main sectors in food industry and economy.

Wheat, a strategic product in Turkey's conditions, is a product that is also important in support policies. It is supported by all of the 941 Agricultural Basins determined in the whole of the country within the scope of the "National Agricultural Project" which is a new supporting instrument and entered into force in Turkey in 2016 (MFAL 2017). Wheat, which is included in the 18 products that are supported under the basin-based support applications, is shown in the group of crops that are experiencing seasonally supply shortage, strategically and locally important, important for human nutrition—health and animal production (MFAL 2017).

As of 2016, there are 2.267.176 farmers registered in the Farmer Registration System in Turkey, and the land size of these farmers is 14.785.863 ha. The total area of wheat produced is 7.6 million hectares (BÜGEM 2017). When the given data are evaluated, it can be said that more than half of the enterprises practice wheat farming. However, further concentration of production in small businesses increases the risk of production. Bayaner (2013) reports that in Turkey, wheat-producing enterprises smaller than 5 hectares constitute 53% of total wheat-producing enterprises and have only 18% of total wheat-cultivated area. For this reason, changes in wheat production due to climate data are more or less influential on the income of agriculture operations in Turkey.

Studies on climatic factors and agriculture interactions maintain their popularity both in the world and in Turkey. There are regional and national studies in this issue (Lobell et al. 2012; Lv et al. 2013; Tack et al. 2015). Prospective simulations can be performed with various calculation tools and models, and the effects of changes in climate parameters on the plant can be revealed (Gowda et al. 2013). The common point here is that climate, plant and soil parameters necessary for modeling are obtained, and the past events are used to calculate possible future changes. There are studies also in Turkey using various modeling methods. Kayam et al. (2002) studied the effects of changes in temperature and precipitation in the Aegean region over the 1970–1999 period on wheat production. In this study, four different climate scenarios including 5% and 10% decreases in monthly precipitation and + 1 °C and + 2 °C increments in monthly average temperatures were prepared and analyzed. Accordingly, when there was a quantitative reduction of 10% in the precipitation of April and May months, a yield reduction of 22.9 kg/ha occurred. Dellal et al. (2004) indicated that climate change will increase its negative effects due to the uncontrolled release of greenhouse gases, and as a result of it, the agricultural sector will not be sustainable. Dellal and McCarl (2007) have reported that temperature increases have reduced the volume of irrigation water and lead to an increase in demand for off-farm water. Similarly, they emphasized that it reduces the duration of snowfall and causes the lack of adequate water in summer. Başoğlu and Telatar (2013) have shown that changes in precipitation affect the share of the agricultural sector in the gross domestic product (GDP), while temperature changes affect negatively. Bayraç and Dogan (2016) expressed that the changes in agricultural yield and precipitation are a positive and significant effect on agricultural GDP. In addition, they stated that changes in CO_2 emissions will have a significant and negative impact on agricultural GDP, and temperature changes had an adverse effect on the agricultural sector. Eruygur and Özokcu (2016) modeled the wheat yield for estimating the long term, and it was stated that wheat yields in all regions of Turkey would fall 8% averagely. They tried to estimate the effects of changes related to climatic factors on general or product basis in these studies.

The most important parameters of climatic factors in plant growth are temperature and precipitation (Brouwer and Heibloem 1986). The lack or excess of these parameters leads to drought phenomenon. The drought phenomenon is the most important climatic consequence which causes loss of yield in agriculture. Changes in temperature and amount of precipitation and their periods bring climate change to the agenda. Climate change, together with global warming, results in drought (Kapluhan 2013). This situation is being dimensioned as an element to increase the risk in terms of agriculture sector. In terms of the possible effects of global warming, it is estimated that Turkey is among the risk group countries and will be affected more by the climate change, especially in the Mediterranean and Central Anatolia regions in the future. Considering that one of the main corps of Central Anatolia Region is wheat, it can be said that the climate change in Turkey will have serious effects on wheat farming.

In this study, the long-term relation of wheat yield with temperature and precipitation from climatic factors was determined with the help of panel data set. Estimations were also made by using variant econometric methods using panel data set. While making these estimates, meteorological drought map of 2017 of Turkey Meteorology General Directorate was utilized. According to the regions in the map created by Turkey Meteorology General Directorate, three different drought groups were identified. The study has been carried out with the created dataset from provinces grouped as slight drought, moderate drought and severe drought regions, and the results were evaluated. In this study, considering the map of Turkey 2016 drought, the effects of temperature and precipitation changes on wheat yield were assessed in different degrees of drought. Research area, Turkey, is an important region that largely in Asian Continent as geopolitics, but also connects to Europe Continental with the Thrace Region. The study also has the feature of being one of the few studies that are modeled according to a regional basis/drought grades and researched by panel data analysis.

2 Materials and methods

In the study, between 1997 and 2016, the average annual temperature, annual average precipitation and the wheat yield per decare were analyzed with the panel data set. The study was carried out in three regions, in terms of meteorological drought grade by considering regions expressed by the General Directorate of Meteorology of Turkey in the year 2017 meteorological drought map (MGM 2017). These regions are slight, moderate and severe drought regions. There are 10 provinces in slight drought region, 8 provinces in moderate drought region and 9 provinces in severe drought region. Definitions and sources of the variables used in the research are shown in Table 1.

Three different drought regions were investigated in the study. The descriptive statistics of the variables used in the analysis of these regions are given in Table 2.

Variables included in the study belong to the years 1997–2016. Between these years, the changes shown by the variables are given in Fig. 1.

The temperature, precipitation and yield values in the analyzed regions were converted to logarithmic form. The functional relationship between wheat yield and climatic factors can be expressed in Eqs. (1), (2) and (3).

$$\ln \mathrm{SLD}\Psi_{it} = f(\ln \mathrm{SLD}\mu_{it}, \ln \mathrm{SLD}\varphi_{it}) \tag{1}$$

$$\ln \mathrm{MD}\Psi_{it} = f(\ln \mathrm{MD}\mu_{it}, \ln \mathrm{MD}\varphi_{it}) \tag{2}$$

$$\ln \mathrm{SVD}\Psi_{it} = f(\ln \mathrm{SVD}\mu_{it}, \ln \mathrm{SVD}\varphi_{it}) \tag{3}$$

The following econometric analyses were carried out in the study with the variables taken into account:

Table 1 Definitions of variables used in the research

Variables	Symbol	Unit	Data source
Yield	Ψ	Kg/ha	TURKSTAT
Temperature	μ	Celsius degree	Turkey Meteorology General Directorate
Precipitation	φ	Millimeter or kg/cm^2	Turkey Meteorology General Directorate
Slight drought	SLD		
Moderate drought	MD		
Severe drought	SVD		

Table 2 Descriptive statistics of variables

	SLD			MD			SVD		
	Ψ	φ	μ	Ψ	φ	μ	Ψ	φ	μ
Mean	230.87	51.96	13.43	247.34	59.89	14.10	257.36	54.62	16.56
Median	229.50	42.74	12.99	230.50	51.60	13.05	250.00	50.22	17.05
Maximum	398.00	171.54	18.65	465.00	159.63	19.85	501.00	116.74	20.69
Minimum	75.00	19.64	9.55	94.00	23.28	8.46	48.00	21.11	12.26
SD	57.75	26.63	1.91	87.19	28.14	3.23	89.51	20.29	1.96
Skewness	0.31	1.42	0.39	0.40	1.20	0.22	0.20	0.76	−0.28
Kurtosis	3.43	5.20	2.28	2.30	4.33	1.63	2.63	3.05	1.93

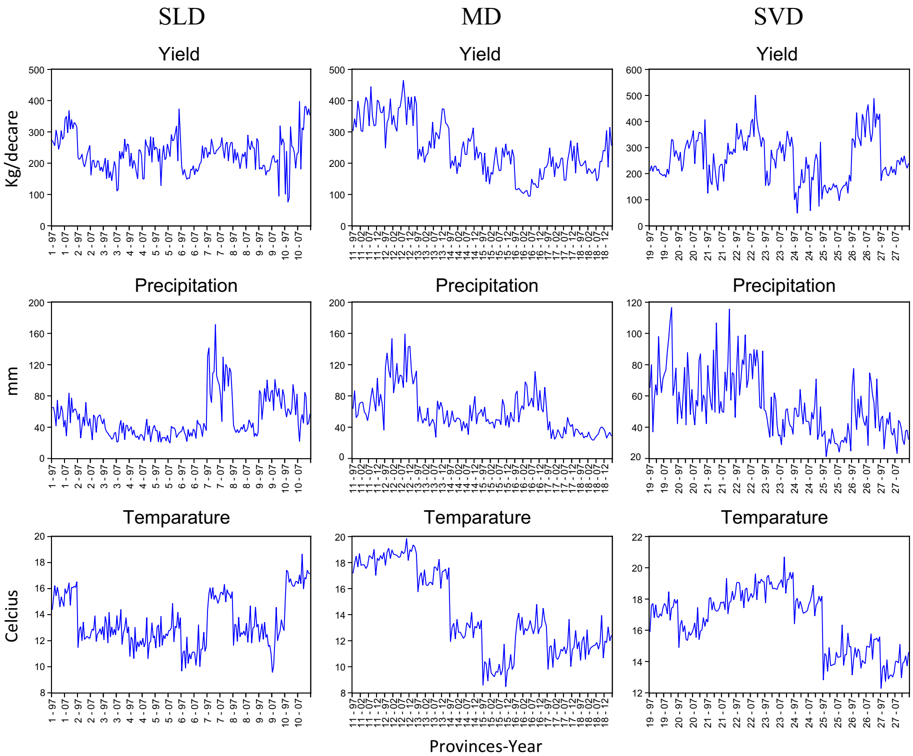

Fig. 1 Trend of the variables (yield, precipitation and temparature) between 1997 and 2016 years by the SLD, MD and SVD regions

- Panel unit root test (LLC and IPS)
- Panel cointegration analysis
- Panel FMOLS analysis
- Panel VECM analysis.

2.1 Panel unit root test

Unit root tests suitable for the data set used in the research have been carried out. Whether the series are affected by their own values in previous periods is investigated with the unit root test. In the series affected by their own values, spurious regression problem arises. Spurious regressions quantitative results do not contain accurate information. The proposed self-associated model for the panel dataset can be written as:

$$\ln Y_{it} = \rho_i \ln Y_{it-1} + \delta_i \ln X_{it} + \varepsilon_{it} \tag{4}$$

where $i = 1, \ldots, N$ is cross-sectional data (27 provinces), $t = 1, \ldots, N$ is number of observations belonging to units (20 years between 1997 and 2016), N is the number of units in the model, t is the number of observations belongs to each unit, ε_{it} is the error term of the ith economic unit during time period t. It is assumed that ε_{it} error term is independent for all times and units and is distributed as $\text{IID}(0, \sigma^2)$ (Maddala 2001). Furthermore, it is also assumed that ρ_i self-coupling coefficients are identically independent for all times and units. If $|\rho_i| < 1$, the series of Y_i is stationary; if $|\rho_i| = 1$, the series of Y_i contains the unit root.

There are several forms of unit root tests, and they have been proposed by various researchers in the literature (Maddala and Shaowen 1999; Kao and Chiang 2000; Hadri 2000; Choi 2001; Im et al. 2003). In this study, LLC—ADF Fisher-IPS and PP Fisher test statistics were used for the unit root test. The LLC unit root tests widely used in panel data stationarity analyses can be explained as in Eq. (5) by the work of Levin et al. (2002). The LLC unit root test varies due to different assumptions about the ρ_i coefficient in Eq. (4) and the test statistics used. In the LLC unit root test, ρ_i coefficients are assumed to be identical for the panel cross sections. This situation can be expressed as $\rho_i = \rho$ for all i's. For the unit root tests based on the ADF principles, the basic notation can be expressed as follows:

$$\Delta \ln X_{it} = \beta_i \ln X_{it-1} + \sum_{j=1}^{n} \theta_{ij} \Delta \ln X_{it-j} + e_{it} \tag{5}$$

where X_{it} is the analyzed variable, e_{it} is the error term and Δ is the difference operator. The appropriate lag length is determined by the Schwarz information criteria (SIC). General evaluation is based on the null hypothesis. The null hypothesis can be expressed as:

$$\begin{cases} H_0 = \beta_i = 0 \\ H_A = \beta_i < 0 \quad \text{for}\, i = 1, 2, 3, \ldots N \\ \qquad \beta_i = 0 \quad \text{for}\, i = N+1, N+2, N+3 \ldots \end{cases} . \tag{6}$$

2.2 Panel cointegration analysis

Based on the panel regression model in the Pedroni's (1999) time series, notations for slight drought, moderate drought and severe drought regions for this research are expressed in Eqs. (7), (8) and (9):

$$\ln \text{SLD}\Psi_{it} = \sigma_i + \delta_{it} + \beta_{it} \ln \text{SLD}\mu_{it} + \beta_{it} \ln \text{SLD}\varphi_{it} + e_{it} \tag{7}$$

$$\ln \text{MD}\Psi_{it} = \sigma_i + \delta_{it} + \beta_{it} \ln \text{MD}\mu_{it} + \beta_{it} \ln \text{MD}\varphi_{it} + e_{it} \tag{8}$$

$$\ln \text{SVD}\Psi_{it} = \sigma_i + \delta_{it} + \beta_{it} \ln \text{SVD}\mu_{it} + \beta_{it} \ln \text{SVD}\varphi_{it} + e_{it} \tag{9}$$

where Ψ_{it}, μ_{it}, φ_{it} are observable variables. In the notation, δ_{it} is the time trend for the cross section i of the time period t, σ_i is the constant coefficient, e_{it} is residue and β_{it} is the slope. This is usually expressed as the cointegration vectors of cross-sectional members in the panel are heterogeneous (Pedroni 1999). The long-term relationship of the $I(1)$ level in the series can be tested by cointegration analysis (Pedroni 1999, 2004). Panel and group statistics and Kao's (1999) test statistics were used. The tests used include different techniques and assumptions. Pedroni offers two types of tests. First consists of the "within-dimension approach" and its four test results and second consists of the "between-dimension approach" and three related test results. Test statistics were evaluated according to the null hypothesis. The hypothesis that there is no cointegration between the series is based on the null hypothesis, while the opposite hypothesis is based on the assumption that there is a cointegration between the series. Kao test statistic is used within the framework of the ADF approach. The statistics are obtained from the least squared dummy variable (LSDV) analysis of the panel (Zoundi 2017). As a result of these statistics, since the coefficients as a majority are considered statistically significant, the null hypothesis was rejected and the existence of a long-term relationship was accepted.

2.3 Panel FMOLS (fully modified ordinary least squares) test

It is possible to evaluate the long-term relation between the considered variables by the panel FMOLS test developed by Pedroni (2000, 2001), because the OLS test may not give effective results. It is also possible to verify the long-term relationship obtained from panel cointegration test by FMOLS test. The FMOLS test has many advantages. Many problems such as serial correlation and the existence of endogenous variables can be overcome both within dimensions and between dimensions. The between-dimensional FMOLS notation, which can be applied separately for slight, moderate and severe drought regions, can be expressed in Eqs. (10) and (11);

$$\Psi^*_{NT} = N^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\mu_{it}-\bar{\mu}_i)^2\right]^{-1}\left[\sum_{t=1}^{T}(\mu_{it}-\bar{\mu}_i)Y^*_t - T\hat{\tau}_i\right] \tag{10}$$

$$\Psi^*_{NT} = N^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}(\varphi_{it}-\bar{\varphi}_i)^2\right]^{-1}\left[\sum_{t=1}^{T}(\varphi_{it}-\bar{\varphi}_i)Y^*_t - T\hat{\tau}_i\right] \tag{11}$$

where the necessary analysis is made, assuming that the related t-statistic is normally distributed.

2.4 Panel VECM (vector error correction model) test

At the end of the procedures described above, stationarity tests were made with panel unit root test, panel cointegration test revealed the existence of a long-term relationship, and panel FMOLS long-term coefficients were obtained. In the next stage, the definitions of causality for the three regions studied were determined by the panel VECM test. The notations for the panel VECM test (Holtz-Eakin et al. 1988; Ciarreta and Zarraga 2010), which were analyzed separately for slight drought, moderate drought and severe drought regions, are given in Eqs. (12) and (13)

$$\Delta(\Psi) = \emptyset_1 + \sum_{k=1}^{m+1} \beta_{1j}\Delta\Psi_{it-j} + \sum_{k=1}^{m+1} \gamma_{1j}\mu_{it-j} + \partial_1 \mathrm{ECT}_{it-1} + \Delta\varepsilon_{1it} \tag{12}$$

$$\Delta(\Psi) = \emptyset_2 + \sum_{k=1}^{m+1} \beta_{2j}\Delta\Psi_{it-j} + \sum_{k=1}^{m+1} \gamma_{2j}\varphi_{it-j} + \partial_2 \mathrm{ECT}_{it-1} + \Delta\varepsilon_{2it} \tag{13}$$

where ECT is the error correction term. The coefficient of the ECT term provides information for the long-term equilibrium level.

3 Results and discussion

The ever-changing climate on the temporal and spatial scales is a dynamic process. In our world, the climate has changed many times up to the present time, but along with the intense industrialization movements in the nineteenth century people began to be influential on the process of natural climate change. The climate change, expressed globally as the increase in temperature and the change in the precipitation regime, is accepted by many peoples in the world, and its results are among the most serious problems humanity faces today. Turkey, especially due to global warming, will be affected by the reduction in water resources, forest fires, drought and desertification along with ecological degradation due to these (Kuzucu et al. 2016). Droughty at the first place of troubles due to global climate change is one of the most important problems likely to happen for Turkey, especially in terms of agricultural sector. Essentially droughty, a problem identified by processes such as "total precipitation reduction, deterioration of the precipitation dispersion balance, impoverishment of river resources, gradual destruction of underground waters, widespread extreme temperatures and its long running," affects not only "soil, water, or agriculture" as it is supposed but also all fields of life from social processes to economy (Drynet 2008).

In this study where the effects of low precipitation and temperature increase factors on wheat yield were examined by panel data analysis, the stationarity of time series was investigated firstly. Granger and Newbold (1974) found that if non-stationary time series are used, spurious regression problems can be encountered. In the analyses performed in time series, the non-stationarity of the series leads to unreliable results among the variables. For this reason, in this part of the study, stationarity conditions using Levin–Lin–Chu, extended Dickey–Fuller (ADF) (1981) and Phillips–Perron Fisher (PP) (1988) tests, the most commonly used methods for testing the stationary properties of the series, are given in Table 3.

When Table 3 is examined, the yield, temperature and precipitation series contain unit root at $I(0)$ level in slight drought, moderate drought and severe drought regions. When the series were differentiated and unit root studies were performed again, it was determined that all the variables examined were stationary at $I(1)$ level. A preliminary information may be generated that the series, which are not stationary at $I(0)$ but stationary at $I(1)$ level, are cointegrated in the long run (Ertek 1996; Tarı 1999; Kutlar 2000). Based on this preliminary information, panel cointegration analysis was performed to investigate the long-term relationships. The results are presented in Table 4.

When Table 4 is examined, it is possible to see a long-term relationship between wheat yield, relationships and temperature in severe drought, moderate drought and slight drought regions. Intra-group and inter-group values giving information about long-term

Table 3 Panel unit root test results

Regions	Unit root test method	Level			First difference		
		Ψ	μ	φ	dΨ	dμ	dφ
		No deterministic intercept and trend			No deterministic intercept and trend		
SVD	Levin–Lin–Chu	0.8480	1.1659	− 1.4628	− 12.5980*	− 17.5878*	− 16.4859*
	ADF Fisher	5.1434	4.3139	12.896	144.101*	203.043*	189.569*
	PP Fisher	4.4488	1.8198	19.0422	189.227*	172548*	187.437*
MD	Levin–Lin–Chu	1.4092	0.7875	− 0.9612	− 10.5291*	− 17.6237*	− 13.6294*
	ADF Fisher	3.7123	4.6968	10.0141	108.491*	189.377*	148.039*
	PP Fisher	3.2706	1.4985	9.0478	172.947*	147.365*	151.342*
SLD	Levin–Lin–Chu	1.2213	0.7557	− 0.7771	− 14.7386*	− 19.3508*	− 16.6990*
	ADF Fisher	5.7747	6.2129	10.8421	180.567*	236.444*	195.476*
	PP Fisher	5.8000	2.3973	11.3245	198.583*	186.540*	204.947*

*Significant at the 1% level

Table 4 Panel cointegration analysis among Ψ, φ and μ

Ψ and μ	SVD Stat.	MD Stat.	SLD Stat.
Common AR coefs. (within dimension)			
Panel v-statistic	0.2687	− 0.0775	− 1.1430
Panel rho-statistic	− 4.6425*	− 4.9398*	− 4.7621*
Panel PP-statistic	− 6.2905*	− 6.1807*	− 7.0391*
Panel ADF-statistic	− 1.3832***	− 1.4717***	− 2.0517**
Individual AR coefs. (between dimension)			
Group rho-statistic	− 3.8249*	− 4.0274*	− 5.6235*
Group PP-statistic	− 8.2907*	− 8.6194*	− 13.6453*
Group ADF-statistic	− 2.4441*	− 1.8459**	− 4.4529*
KAO residual cointegration test results			
ADF	1.9020**	1.4132***	2.2300*
Residual variance	0.0991	0.0327	0.0698
HAC variance	0.0131	0.0118	0.0118

*, **, ***Significant at the 1%, 5%, 10% levels, respectively

relationships are totally statistically significant. In addition, the KAO test statistic is also considered statistically significant. Hence, it is seen that both the precipitation changes and the temperature changes have a long-term effect on wheat yield in Turkey.

If an overall assessment of the results in Table 4 is to be made, they are two important factors that can be considered important for crop yields among climatic factors. The effects of temperature and precipitation parameters on yield are among the main parameters of plant growth models (Jones et al. 2017) as well as being handled by many researchers in the world (Howell et al. 1975; Blum and Pnuel 1990; Loss and Siddique 1994; Zhang et al. 1998; Duivenbooden et al. 1999; Tack et al. 2015).

Long-term effects of temperature and precipitation factors discussed in this study are quantitatively expressed, and it can be said that the factors are interacting with each other. However, it is not possible to comment on the trend and intensity of this relationship through cointegration analysis. Full modified OLS analysis was conducted to reveal the effect of precipitation and temperature on wheat yield, and the results are listed in Table 5. When effect to yield of temperature is examined, it was estimated that a 1% increase in the amount of temperature would result in yield decrease of 0.84% in the severe drought region, 0.43% in the moderate drought region and 0.48% in the slight drought region. When effect to yield of precipitation is considered, it can be predicted that a 1% increase in precipitation will result in yield increase of 0.20% in the severe drought region, 0.12% in the moderate drought region and 0.09% in the slight drought region. The results obtained are similar to the studies conducted in Turkey. Dellal et al. (2004) and Dellal and McCarl (2007) estimate that wheat yields will decrease by 7.5% in 2050 and wheat plantation areas will contract and production will decrease. Şimşek and Çakmak (2012) conducted wheat yield estimation and vulnerability analysis with AgrometShell plant growth model. As a result of the research, according to the scenarios created prospectively for the examined regions, it was reported that a 1 °C increase in temperature would result in a 1.8% wheat yield decrease, and a 2 °C increase in temperature, 20 °C increase in solar radiation and a 20% decrease in precipitation would result in a 18.2% wheat yield decrease. Kayam et al. (2002) investigated the effect of climate change on wheat yield in the Aegean region. They stated that in the regions of precipitation of 500–600 mm, the decrease in precipitation would not be very effective on the yield alone, the 1–2 °C increase in temperature would cause yield decrease by 7.4% but the reduction in precipitation by 10% and the increase in temperature by 2 °C would result in a significant decrease in wheat yield.

In this study where the effects of precipitation and temperature on wheat yield from climatic factors were investigated at three different droughty levels, the coefficients of long-term cointegrated factors were solved with the help of full modified OLS. Short- and long-term causality of variables determined to be cohabited in the long run were tested with panel vector error correction model (VECM) in the long term and Wald test in the short term. Test results are given in Table 6.

Table 5 Panel FMOLS results

Dependent variable: Ψ	φ	μ	
SVD			
B	0.2006*	−0.8401**	$R^2 = 0.74$
S.E.	0.0562	0.3477	Ad. $R^2 = 0.69$
t-stat	3.9948	−2.4156	S.E. of regression = 0.22
MD			
B	0.1154**	−0.4275**	$R^2 = 0.89$
S.E.	0.0521	0.2139	Ad. $R^2 = 0.86$
t-stat	2.2119	−1.9990	S.E. of regression = 0.14
SLD			
B	0.0934**	−0.4751**	$R^2 = 0.58$
S.E.	0.0462	0.1954	Ad. $R^2 = 0.50$
t-stat	2.0228	−2.4305	S.E. of regression = 0.19

*, **Significant at 1% and 5% levels, respectively

Table 6 Panel VECM results among Ψ, φ and μ

	Dependent variables		
	Ψ	φ	μ
Short run			
SVD[c]			
Ψ	72.22*	20.34*	10.90**
φ	2.45	19.27*	31.52*
μ	3.25	4.33	135.41*
Long-run ECT	−0.09***	0.07	0.01
Short run			
MD[b]			
Ψ	23.50*	3.63	1.95
φ	6.32	46.94*	9.05**
μ	9.17***	5.67	113.91*
Long-run ECT	−0.11**	−0.15	0.02
Short run			
SLD[a]			
Ψ	10.92*	4.57	4.01
φ	2.51	61.10*	29.07*
μ	5.42	9.36**	66.62*
Long-run ECT	−0.48*	−0.17	0.08*

*, **, ***Significant at 1%, 5%, 10% levels, respectively

[a]Optimal lag: 3, [b]Optimal lag: 4, [c]Optimal lag: 4

When the vector error correction model results are examined, in the short term, there is no causality to wheat yield from climatic factors in all three regions. However, in all three regions, the bidirectional causality relationship between climatic factors was found to be statistically significant in the short term. In the long run, the ECT coefficients were statistically significant in the three regions for the yield parameter. The imbalance of 0.08% in severe drought, 0.17% in moderate drought and 0.48% in slight drought regions in yield parameters due to climatic factors will disappear in 12,5, 6 and 2 years for severe, moderate and slight drought regions, respectively.

4 Conclusion

In this study, the effects of climatic factors on wheat yield were investigated in the three regions situated in different degrees of drought formed by the Turkey drought map. Precipitation and temperature were determined as climatic factors. The study covers the years 1997–2016. The research was analyzed by using panel data set. Panel unit root tests, panel cointegration test, panel FMOLS and panel VECM tests from panel data analyses were used. Practicing of wheat growing in drought and semi-drought areas of Turkey mostly depending on precipitation, and especially dry and high temperatures during the growth period of the grain, results in significant decrease in productivity. Due to the increasing population density and decreasing arable land, future food shortages may be experienced; therefore, it has become very important to reduce product losses caused by high-temperature effects in our world. For this reason, breeding studies on tolerant to biotic and abiotic conditions, especially droughty tolerance, are important. The statistics of past turnover in the current system are important in terms of putting forward the existing developments.

In particular, plant type and reactions of varieties considered in climate models are important in terms of prospecting the success of the studies and planning for the future. Both the studies in Turkey and in the world trying to model the adverse effects of global climate change, and the results show that changes in temperature and precipitation will cause a loss of efficiency in the existing system. The studies in Turkey foresee the decrease and changes in the production regions due to climate change, especially in wheat. As a result of these studies, these reductions are seen in the model, and it seems that a very low proportion of the long-expected decreases in the current development and climate trend can be tolerated in the short term. This study showed that both breeding and production system studies related to wheat that we have defined as strategic crop for Turkey have importance in terms of adaptation to climate change. In Turkey, where strategic products are supported, climate change and expectations should be considered in the basin-based support policies of Turkey in the medium and long terms. The plans made with the current situation may not meet the expectations for the future. For this reason, more involvement of decision support systems and models in strategy and planning is important for adaptation to climate change.

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