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Examination of meat, milk, and egg production in Turkiye using Trend models

Examen de la producción de carne, leche y huevos en Turquía mediante modelos de Tendencias

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ABSTRACT

The rising global demand for animal products due to world population growth highlights the need for taking significant steps in animal husbandry. Understanding the impact of advancements in animal husbandry on the production of animal products would help to identify sectoral deficiencies and to develop future strategies. The aim of this study was to determine variations in the indicators of animal products in Turkiye considering species and breed differences using trend analysis. The dataset covers data from 1991 to 2019 for milk and from 2001 to 2023 for egg production, red meat, and white meat production, obtained from the Turkish Statistical Institute. To determine trends in the time series of animal product parameters, the Nonparametric Modified Mann-Kendall (MMK) test, Sen's innovative (ST) trend test, Spearman's rho (SR) test, Wald-Wolfowitz (WW) test, Cox-Stuart (CS) trend test, and Robust Rank – Order Distributional (RR) test were employed. To identify significant change-points in the time series, the Pettitt test was used. The results of the SR and MMK tests revealed the presence of upward trends in red meat production from Cattle, Sheep, Buffalo, and Goat; white meat production; egg production; as well as milk production from Sheep (Merino), Goat (Anatolian Black), Cattle (Dairy) and Cattle (Crossbred). Furthermore, an increasing trend was observed in the SR test for Goat (Anatolian Black) milk production. The WW and RR tests showed downward trends in the time series of milk production for Goat (Anatolian Black), Cattle (Domestic), and Buffalo. Upward trends were identified using the ST and CS methods in red meat production from Cattle, Sheep, and Goat; white meat production; and egg production. The results suggest that economic incentives and policies, as well as diseases, are significant factors for trends in animal husbandry. Consequently, increasing incentives and policies for animal husbandry and expanding cooperatives are important to support animal husbandry practices.

Key words: Trend analysis; meat production; milk production; production trends; livestock in Turkiye

RESUMEN

El aumento de la demanda mundial de productos animales debido al crecimiento de la población mundial pone de relieve la necesidad de tomar medidas importantes en la cría de animales. Comprender el impacto de los avances en la cría de animales sobre la producción de productos de origen animal, ayudaría a identificar las deficiencias del sector y a desarrollar futuras estrategias. El objetivo de esta investigacion fue determinar las variaciones de los indicadores de productos animales en Turkia teniendo en cuenta las diferencias entre especies y razas mediante el análisis de tendencias. El conjunto de datos abarca datos de 1991 a 2019 para la producción de leche y de 2001 a 2023 para la producción de huevos, carne roja y carne blanca, obtenidos del Instituto Turco de Estadística. Para determinar las tendencias en las series temporales de los parámetros de los productos animales se emplearon la prueba no paramétrica de Mann-Kendall (MMK) modificada, la prueba de tendencia innovadora de Sen (ST), la prueba rho de Spearman (SR), la prueba de Wald-Wolfowitz (WW), la prueba de tendencia de Cox-Stuart (CS) y la prueba de distribución robusta de rango y orden (RR). Para identificar puntos de cambio significativos en las series temporales, se utilizó la prueba de Pettitt. Los resultados de las pruebas SR y MMK revelaron la presencia de tendencias al alza en la producción de carne roja de Bovino, Ovino, Búfalo y Caprino; la producción de carne blanca; la producción de huevos; así como la producción de leche de Ovino (Merino), Caprino (Negro de Anatolia), Bovino (Lechero) y Bovino (Cruzado). Además, se observó una tendencia creciente en la prueba SR para la producción de leche de Cabra (Negra de Anatolia), Vacuno (Doméstico) y Búfalo. Con los métodos ST y CS se identificaron tendencias al alza en la producción de carne roja de vacuno, ovino y caprino; en la producción de carne blanca; y en la producción de huevos. Los resultados sugieren que los incentivos y las políticas económicas, así como las enfermedades, son factores significativos de las tendencias en la cría de animales. Por lo tanto, el incremento de incentivos y politicas para la cria animal y la expansion de cooperativas son de importancia para soportar las practicas de cria animal.

Palabras clave: Análisis de tendencias; producción cárnica; producción lechera; tendencias de producción; ganadería en Turquía

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INTRODUCTION

The rising global demand for animal products, driven by population growth, highlights the need for substantial advancements in animal husbandry. Demand for animal products is expected to double after 40 years. Consequently, increasing animal production and ensuring efficient resource consumption are essential. While the animal husbandry industry in developed countries is well-developed and capable of meeting demand, the situation in undeveloped and developing countries falls short of the desired level [1 , 2]. In addition to meeting domestic demand, animal husbandry has important roles such as generating employment, creating export opportunities, and supporting industries with by-products including fleece wool and leather [3]. Furthermore, animal husbandry accounts for 40% of the income generated in the agricultural sector globally [4].

Turkiye is a well-suited country for agriculture and animal husbandry due to its advantageous geographical location, as well as land and climate diversity [5]. Although Türkiye's agricultural production can largely meet domestic demand, the situation is different in the red meat industry. The primary reason for this is the relatively low share of animal husbandry, which accounts for 25% of overall agricultural production. On the contrary, this ratio is typically 40% in the developed countries, Moreover, Turkiye's red meat production has not reached the desired level due to several factors including high production costs, rural-urban migration, and marketing challenges. In addition, the low number of raised cattle breeds and insufficient feeding of animals due to high feed costs are among the factors contributing to this result [6 , 7 , 8]. Small ruminant livestock, another source of red meat, are typically raised in areas such as infertile pastures, mountainous regions, and stubble fields in Turkiye. Carrying out small ruminant livestock practices through traditional methods leads to lower yields per unit in meat and milk production compared to developed countries [9 , 10].

While the small ruminant (*Ovis aries* and *Capra hircus*) and bovine (*Bos taurus* and *Bubalus bubalis*) livestock sectors in Turkiye have not reached the desired level, the poultry (*Gallus gallus* domesticus) sector has shown rapid development in parallel with global trends. After efforts to improve the white meat sector, the production cycle has been shortened, and integrated facilities have become self-sufficient [11]. Although the poultry sector was disrupted by avian influenza cases in 2005 – 2007, it quickly recovered due to an effective vaccination program and modern facilities. Furthermore, the egg sector, like the white meat sector, is one of the continuously developing sectors in Turkiye. The egg sector in Turkiye can meet domestic demand and generate foreign currency inflow through exports [12].

Upward or downward trends in the indicators of agricultural and livestock production are critical parameters for countries; due to this importance, many trends analysis studies have been conducted in this field. For instance, Oladimeji identified the trends in fish production and consumption parameters in Nigeria from 1970 to 2014 using graphical methods and Pearson's correlation coefficient; They reported a linear increase in production and consumption after 1980 [13]. Aşkan and Dağdemir (2017) [14] examined broiler chicken production in Turkiye from 2000 to 2015 using trend analysis and identified a linear increase.

A literature survey revealed that no study has yet graphically examined variations in livestock production parameters using six different trend techniques simultaneously [15 , 16]. Accordingly, this study aims to examine significant variations in long-term livestock production parameters in Turkiye using trend analysis, taking into account species differences. The results would be of great importance for determining the paths that different livestock performance parameters follow over time. Plus, addressing the reasons for upward or downward trends is expected to make a valuable contribution to the current literature. By using six different trend techniques together in the analysis of these indicators and statistically determining the possible change-points in the time series, this study is the first of its kind in the field in Turkiye.

MATERIAL AND METHODS

The dataset used consists of annual milk, egg, red meat, and white meat production data for various animal species and breeds obtained from the Turkish Statistical Institute (TurkStat). The dataset covers data from 1991 to 2019 for milk production and from 2001 to 2023 for egg, red meat, and white meat production [17]. The meat production parameters were presented in tons, while egg production was measured in pieces (units). While selecting variables, both production and consumption quantities across the country, as well as their added value to the national economy, were considered. (TABLE I).

A trend refers to the upward or downward progression of a dependent variable over a given time series. A trend can follow a linear or curvilinear path. Trend analysis, on the other hand, is the examination of whether a given trend in a time series is statistically significant [18]. To identify trends in the livestock performance indicators, the Nonparametric Modified Mann-Kendall (MMK) test, Sen's innovative (ST) trend test, Spearman's rho (SR) test, Wald-Wolfowitz (WW) test, Cox-Stuart (CS) trend test, and Robust Rank-Order Distributional (RR) tests were employed. In addition, to identify significant breakpoints in the time series, the Pettitt test was conducted. All statistical analyses were performed with R statistical programming language (version 4.2.1; The R Foundation for Statistical Computing, Vienna, Austria; https://www.r-project.org) [19].

TABLE I.

Statistical properties of the performance indicators

Performance Indicators	Type (Species)	Min.	Max.	SD	M	Period
Meat	Cattle (Bos taurus)	488.556	1.670.606	389.056	871.475	2001 – 2023
	Buffalo (Bubalus bubalis)	3.785	15.386	3.082	6.247	
	Sheep (Ovis aries)	186.121	569.066	100.262	263.389	
	Goat (Capra hircus)	42.845	128.989	23.144	67.736	
Poultry meat	Chicken (Gallus gallus)	614.745	2.417.995	583.256	1.571.618	
Egg	Chicken	10.575.046	20.637.732	3.504.693	15.474.554	
Dairy Production	Sheep (Domestic)	645.465	1.449.350	210.357	927.993	1991–2019
	Sheep (Merino)	11.922	72.104	16.679	26.587	
	Goat (Anatolian Black)	190.285	573.785	113.180	317.731	
	Goat (Angora)	1.924	12.655	2.827	4.609	
	Cattle (Culture)	1.913.438	12.544.507	3.454.214	5.378.857	
	Cattle (Crossbred)	3.867.656	7.473.386	973.387	5.143.999	
	Cattle (Domestic)	764.030	2.514.575	492.373	1.505.344	
	Buffalo	8.670	161.348	38.548	71.852	

Min.: Minimum Max.: Maximum SD: standard deviation M: Mean

Modified Mann-Kendall (MMK) trend test

The MMK method is a nonparametric test used to identify trends in a given time series. In this method, if the examined dataset is higher (lower) than the subsequent one, -1 (+1) is added to the Mann–Kendall (MK) statistics (S) (1). Where (i) varies from 1 to n-1 and (j) varies from i+1'den to the data length n. This operation is repeated for the entire dataset and the sum of S statistics is computed (2):

$$\operatorname{sign}\left(z_j - z_i\right) = \begin{cases} 1 & if \quad z_j > z_i \\ 0 & if \quad z_j = z_i \\ -1 & if \quad z_j < z_i \end{cases} \tag{1}$$

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(z_j - z_i\right) \tag{2}$$

S is assumed to have a normal Probability Distribution Function (PDF) with a mean of zero and a specified variance (3 and 4). Furthermore, the null hypothesis H_0 assumes that there is no trend in the given time series. If H_0 is rejected, it indicates that the alternative hypothesis H_1 is significant, which suggests that there is a trend in the time series. This decision is based on specific values of the test statistics z and the chosen significance level (5). If the calculated z value, Z_{caj}, exceeds the tabulated normal distribution value, Z_{tab} for the significance level (α), the trend in the time series is considered statistically significant [20 ,21].

$$E(S) = 0, \tag{3}$$

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5)}{18}, \tag{4}$$

$$z = \begin{cases} \dfrac{S-1}{Var(S)} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{Var(S)} & \text{if } S < 0 \end{cases} \tag{5}$$

Sen trend (ST)

This approach involved splitting the given time series into two series. In ascending order, the first half of the series is plotted on the horizontal axis and the second half on the vertical axis with a 1:1 (45°) straight line. The distribution of the data above the 1:1 line indicates a monotone upward trend, whereas if the distributed data is below the 1:1 line there is a monotone downward trend. On the other hand, scattering of the data on or around the 1:1 line indicates there is no significant trend in the time series (FIG. 1). The data range on the horizontal axis can be split into subcategories as low, moderate, and high [22 ,23].

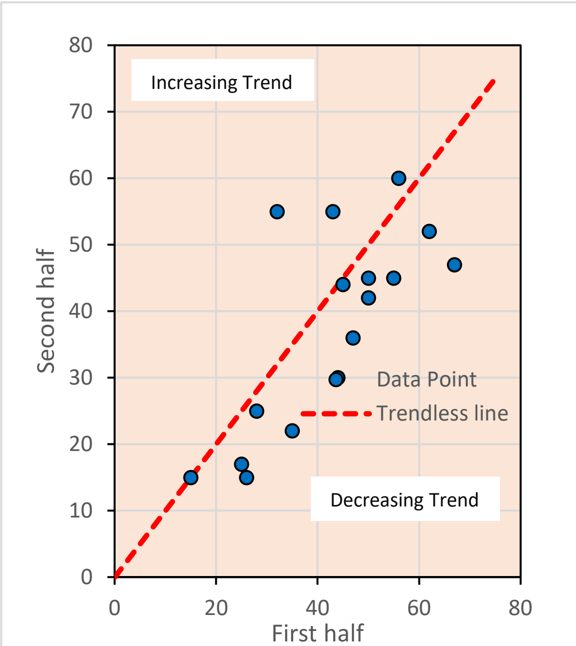

FIGURE 1. Illustration of increasing, decreasing, and no trends in the ST method

Initially, trend slopes are interpreted graphically but later Şen introduced a mathematical method [24]. A trend slope is calculated using Equation (6), where n represents the data length of the primary time series and $\bar{x}$ ($\bar{y}$) first (second) average half-time series. The trend curve is plotted using Equation (7). Confidence limits (CL) for ST can be computed using trend slope, S_{ST}, expectation for no trend ($E(S_{ST}) = 0$), and standard deviation (SD) of two halves ($\sigma_x = \sigma_y = \sigma / \sqrt{n}$); where σ represents the standard deviation of primary time series. SD of trend slope, σ_s is computed by Equation (8), where $p_{\bar{x}\bar{y}}$, represents the cross-correlation coefficient between the first and second half series. CL is calculated using Equation (9), where, S_{cri} is the critical standard deviation for standardized time series at ±1.96 (1.65) for 95% (90%) significance (α) [25].

$$s_{ST} = \frac{2(\bar{x} - \bar{y})}{n} \quad (6)$$

$$y = x + s \quad (7)$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{1 - p_{\bar{x}\bar{y}}} \quad (8)$$

$$CL_{(1-\alpha)} = 0 \pm s_{cri}\sigma_s \quad (9)$$

Spearman's rho (SR)

Spearman's rho (SR) is a nonparametric measure of rank-order correlation coefficient between two variables. SR test is a simple method with monotonic power for identifying linear and nonlinear trends[26]. In this method, rejecting H_0 indicates the presence of an increasing or decreasing trend[27]. SR test statistic is defined as D (10) and standardized test statistics Z_{SR} (11):

$$D = 1 - \frac{6\sum_{i=1}^{n}(R_i - i)^2}{n(n^2 - 1)} \quad (10)$$

$$Z_{SR} = D\sqrt{\frac{n - 2}{1 - D^2}} \quad (11)$$

Where R_i represents the rank of the X_i measure and n is the length of the time series. A positive Z_{SR} value indicates the presence of an increasing trend in the time series, whereas a negative value indicates a decreasing trend. When $|Z_{SR}| > t_{\left(n-2,\ 1-\frac{\alpha}{2}\right)}$, H_0 is rejected. and the trend in the times series is considered significant. $t_{\left(n-2,\ 1-\frac{\alpha}{2}\right)}$ is the critical value of t in the Student's t-distribution table for the 5% significance level [28].

Cox-Stuart (CS) Trend

CS is a nonparametric trend test like the MK test. This method evaluates increasing or decreasing trends without assuming linearity. Despite its limited application, CS is a powerful test for identifying trends in datasets. The theoretical basis of the test is the binomial distribution [29 , 30]. For conducting a CS test, firstly, the time series is divided into three sub-series. It is checked whether the data in the first part are higher than the data in the final part. For *n* > 30, the test statistic of the Cox-Stuart trend test is given in Equation (12):

$$Z = \frac{\left|S - \frac{n}{6}\right|}{\sqrt{\frac{n}{12}}} \quad (12)$$

Where S represents the maximum number of the data points either signed as + or –. The z-statistics is normally distributed. For $n \leq 30$, a continuity correction of –0.5 is added to the denominator [31].

Robust Rank-order distributional (RR)

The non-parametric RR test is conducted to identify differences in location within the dataset when the assumption of variance homogeneity is not satisfied. The RR test is less affected by non-normal distribution and the presence of outliers [32]. *X* and *Y* represent two samples of a continuous variable with sizes n_x and n_y (13). Initially, the merged sample is arranged in ascending order. s_{xi} and s_{yi} represent the numbers of *Y* (*X*) values with a lower rank than xi (yj) (14). The mean numbers are given in Equation (13):

$$\bar{s}_x = \frac{\sum_{i=1}^{n_x} s_{xi}}{n_x} \text{ and } \bar{s}_y = \frac{\sum_{j=1}^{n_y} s_{yj}}{n_y} \quad (13)$$

Variance:

$$s_{Sx}^2 = \sum_{i=1}^{n_x} (s_{xi} - \bar{s}_x)^2 \text{ and } s_{Sy}^2 = \sum_{j=1}^{n_y} (s_{yj} - \bar{s}_y)^2 \quad (14)$$

Test statistic:

$$z = \frac{1}{2} \frac{n_x\bar{s}_x - n_y\bar{s}_y}{\left(\bar{s}_x\bar{s}_y + s_{Sx}^2 + s_{Sy}^2\right)^{\frac{1}{2}}} \quad (15)$$

$|z| > z_{1-\alpha/2}$ indicates that the two samples have significantly different location values Equation (15) [33].

Wald-Wolfowitz (WW)

The Wald-Wolfowitz (WW) test is a nonparametric method used to evaluate the similarity between two datasets [34]. R indicates test statistics of WW. The test statistic for this method is calculated as follows:

The expected value [E(R)] of R is:

$$R = \sum_{i=1}^{n-1} x_i + x_{i+1} + x_1 x_n, \quad E(R) = \frac{S_1^2 - S_2}{n-1} \quad (16)$$

The expected variance:

$$V(R) = \frac{S_2^2 - S_4}{n-1} - E(R)^2 + \frac{S_1^4 - 4S_1^2S_2 + 4S_1S_3 + S_2^2 - 2S_4}{(n-1)(n-2)} \quad (17)$$

s_t statistic of time series (t) with:

$$s_t = \sum_{i=1}^{n} x_i^t, t = 1,2,3,4 \quad (18)$$

For *n* > 10, the statistic is normally distributed:

$$z = \frac{R - E(R)}{\sqrt{V(R)}} \quad (19)$$

Where $x_1, x_2, \ldots, x_n$ represent the sample data. Test statistic computes p-values for the two-sided scenario from the standard normal distribution Equations (16-19).

Pettitt Test

This test is introduced by Pettitt to determine a change-point in a given time series. This test can identify change-points in monthly or annual scales. The null hypothesis suggests that the time series follows a random distribution, while the alternative hypothesis suggests the presence of a breakpoint. The Pettitt test is a non-parametric rank test. The ranks $r_1 \ldots r_n$ of the $Y_1 \ldots Y_n$ are used for the statistic given in Equation (20) [35]:

$$X_k = 2\sum_{i=1}^{k} r_i - k(n+1), k = 1 \ldots n \quad (20)$$

If there is a change-point in year *K*, the statistic is minimum or maximum near the year *k = K*:

$$X_k = \max_{1 \le k \le n} |X_k|$$

The statistical significance for a given α level is calculated as follows:

$$X_{K\alpha} = [-ln\alpha(n^3 + n^2)/6]^{1/2}$$

If X_K values are above the critical values, H_0 is rejected [35].

RESULTS AND DISCUSSION

This study examined indicators for milk, egg, red meat, and white meat production using ST, MMK, SR, WW, RR, and CS nonparametric trend analysis methods. The results are presented in TABLE II. The findings of the SR method are presented as rho and p-values. In ST, MMK, WW, RR, and CS methods, the critical values for the test statistics and p-values were set at a 95% confidence interval. While evaluating the results, Z or s values above the critical value indicate the presence of a significant trend in meat, milk, and egg performance indicators. The direction of a trend is determined by the sign of the Z or s value. A positive sign indicates an increasing trend, while a negative sign means a decreasing trend.

TABLE II .

Results of the trend analysis for time series of production indicators

Method	Significant trends	Increasing trends	Decreasing trends	No trends
SR	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Angora, Goat Anatolian Black, Buffalo, Cattle Domestic, Cattle Culture, and Cattle Crossbred)	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Anatolian Black, Cattle Culture, and Cattle Crossbred species)	MILK PRODUCTION (Goat Angora, Cattle Domestic, and Buffalo)	MILK PRODUCTION (Sheep Domestic)
MMK	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Angora, Buffalo, Cattle Domestic, Cattle Culture, and Cattle Crossbred)	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Cattle Culture, and Cattle Crossbred species)	MILK PRODUCTION (Goat Angora, Cattle Domestic, and Buffalo)	MILK PRODUCTION (Sheep Domestic and Goat Anatolian Black)
ST	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Angora, Goat Anatolian Black, Buffalo, Cattle Domestic, Cattle Culture, and Cattle Crossbred)	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat species) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Anatolian Black, Cattle Culture, and Cattle Crossbred species)	MILK PRODUCTION (Goat Angora, Cattle Domestic, and Buffalo)	MILK PRODUCTION (Sheep Domestic)
CS	RED MEAT PRODUCTION (Cattle, Sheep, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Angora, Goat Anatolian Black, Cattle Culture, Cattle Crossbred, and Cattle Domestic species)	RED MEAT PRODUCTION (Cattle, Sheep, and Goat species) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Anatolian Black, Cattle Culture, and Cattle Crossbred species)	MILK PRODUCTION (Goat Angora and Cattle Domestic)	RED MEAT PRODUCTION (Buffalo) MILK PRODUCTION (Sheep Domestic and Buffalo)
RR	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Angora, Goat Anatolian Black, Buffalo, Cattle Domestic, Cattle Culture, and Cattle Crossbred species)	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Anatolian Black, Cattle Culture, and Cattle Crossbred species)	MILK PRODUCTION (Goat Angora, Cattle Domestic, and Buffalo)	
WW	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Anatolian Black, Goat Angora, Buffalo, Cattle Domestic, Cattle Culture, and Cattle Crossbred species)	RED MEAT PRODUCTION (Cattle, Sheep, Buffalo, and Goat) WHITE MEAT PRODUCTION EGG PRODUCTION MILK PRODUCTION (Sheep Merino, Goat Anatolian Black, Cattle Culture, and Cattle Crossbred species)	MILK PRODUCTION (Goat Angora, Cattle Domestic, and Buffalo)	

SR= Spearman's rho test; MMK= Nonparametric Modified Mann-Kendall test; ST= Sen's innovative trend test; CS= Cox-Stuart trend test; RR= Robust Rank-Order Distributional tests; WW= Wald-Wolfowitz test.

The results of the SR test revealed the presence of increasing trends in red meat production for Cattle, Sheep, Buffalo, and Goat species; white meat production; egg production; as well as milk production for Sheep (Merino), Goat (Anatolian Black), Cattle (Dairy) and Cattle (Crossbred) species. On the contrary, decreasing trends were identified in milk production for Goat (Angora), Buffalo, and Cattle (Domestic). However, no trend was observed in Sheep (Domestic) milk production. According to the MMK test results, increasing trends were identified in Beef, Sheep, Buffalo, and Goat meat production; white meat production; egg production; as well as in milk production from Sheep (Merino), Cattle (Dairy), and Cattle (Crossbred). Additionally, decreasing trends were observed in milk production from Goat (Angora), Buffalo, and Cattle (Domestic). However, no trend was observed in milk production from Sheep (Domestic) and Goat (Anatolian Black). The SR test yielded a similar finding as the MMK test. Although an increasing trend in Anatolian Black goat milk production was observed in both the SR and MMK tests, this trend was not statistically significant in the MMK test (TABLE II).

Both WW and RR methods yielded the same results. The trends observed in the time series for performance indicators were significant in both methods. For milk production, decreasing trends were observed for Goat (Angora), Cattle (Domestic), and Buffalo, whereas increasing trends were identified for Sheep (Domestic), Sheep (Merino), Goat (Anatolian Black), Cattle (Culture), and Cattle (Crossbred). In addition, increasing trends were found in Beef, Buffalo, Sheep, and Goat meat, white meat, and egg production.

The CS method results indicated the presence of increasing trends in Beef, Sheep, and Goat meat production; white meat production; and egg production. For milk production, positive trends were observed for Cattle (Crossbred), Cattle (Culture), Goat (Anatolian Black), and Sheep (Merino) species. On the contrary, decreasing trends were found in the Goat (Angora) and Cattle (Domestic) milk production. However, no trend was observed in the time series of buffalo meat production, as well as buffalo and sheep milk production. The results obtained by the ST method were similar to those obtained by the CS technique. However, while no significant trend was observed in buffalo milk production with the CS technique, a downward trend was identified using the ST method (TABLE II). It is believed that discussing the results obtained through trend analysis methods in relation to the literature would offer valuable information about economic incentives and implemented policies in animal husbandry, as well as disease trends. A decreasing trend was observed in Buffalo meat and milk production until 2010, followed by an increasing trend after 2010. The Turkish Ministry of Agriculture and Forestry has increased support and incentives for buffalo production. Additionally, producers shifted to intensive production driven by rising demand. These factors have played a significant role in the increase in Buffalo production [36]. There was a decrease in sheep and goat breeding from 2007 to 2009 due to factors such as severe drought, reduced feed raw material production, and higher prices. However, in 2007, the establishment of Breeding Sheep and Goat Breeders' Associations and the implementation of the Turkish Ministry of Agriculture and Forestry's national "Improvement in Animal Breeding through Public" project led to a rapid upward trend in both meat and milk production from sheep and goat starting in 2010 [37]. The reasons underlying the increasing trend in the poultry sector were analyzed, and it was understood that the poultry sector developed much faster compared to other sectors with the rise in modern production facilities in Turkiye during the 1990s and the transition to European production standards in the 2000s. Despite the disruption in the sector in 2005 due to the avian influenza outbreak in Turkiye, the industry showed a rapid recovery and maintained its upward trend [38]. As a result of the support and incentives provided by the Turkish Ministry of Agriculture and Forestry for cattle breeding, a decreasing trend in the number of domestic breed cattle and increasing trends in the number of crossbred and dairy cattle were observed. However, due to inadequate production conditions, misguided policies, high feed raw material costs, and the oligopolistic market structure, red meat and milk production in Turkiye have not reached the desired levels [39].

As shown in FIG. 2, increasing trends were observed in Beef, Buffalo, Sheep, and Goat meat production, as well as for white meat and egg production curves. However, a Pettitt test was conducted to identify the presence of a change-point in the performance indicators. Accordingly, significant change-points were identified in the time series for Buffalo, Sheep, and Goat meat production as well as for egg production. These significant change-points were observed in 2013 for Buffalo meat production (U=88, α=0.05, P=.016), 2011 for Sheep meat production (U=108, α=0.05, P=.001), 2012 for Goat meat production (U=108, α=0.05, P=.001), and 2011 for Egg production (U=108, α=0.05, P=.001).

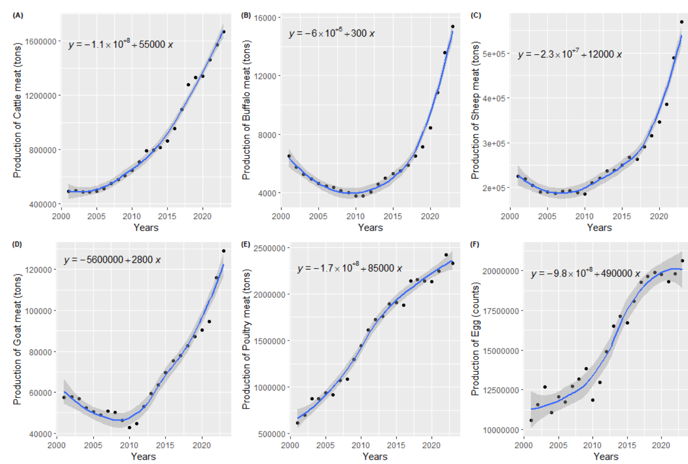

FIGURE 2. Time series and trend curves for species-based red meat production, white meat production, and egg production

Trend curves for Sheep (Domestic), Sheep (Merino), Goat (Angora), Goat (Anatolian Black), Cattle (Culture), Cattle (Crossbred), Cattle (Domestic) and Buffalo milk production are given in FIG. 3. The graphs for Sheep (Domestic), Sheep (Merino), Goat (Anatolian Black), Cattle (Culture), and Cattle (Crossbred) milk production show a general increase, while an overall decreasing trend is observed in milk production from Cattle (Domestic), buffalo, and Goat (Angora). Furthermore, the Pettitt test revealed the presence of change-points in the time series for Sheep (Domestic), Goat (Anatolian Black), Goat (Angora), Cattle (Crossbred), Cattle (Domestic), and Buffalo milk production. According to the Pettitt test, significant change-points were observed in 2010 for Sheep (Domestic) milk (U=152, α=0.05, P=.008), 2009 for Goat (Anatolian Black) milk (U=178, α=0.05, P=.001), 2005 for Goat (Angora) milk (U=204, α=0.05, P<.001), 2009 for Cattle (Crossbred) milk (U=188, α=0.05, P<.001), 2007 for Cattle (Domestic) milk (U=192, α=0.05, P<.001), and 2001 for Buffalo milk (U=182, α=0.05, P<.001) production.

Çiçek and Doğan [40] analyzed producer prices for livestock feed and beef in Turkiye between 1988-2017 using Linear, Quadratic, Exponential, and S-curve trend models. Their findings revealed that the cattle population exhibited a rapid increase between 2003-2009 and 2010-2016, whereas the number of ovine animals showed a downward trend until 2010. In the current study, on the other hand, species- and breed-based analysis enabled the identification of which species or breed contributed most significantly to the downward or upward trends. According to the obtained results, the cow milk demand was predominantly met by domestic cattle until 2000 but after this period, a notable shift was observed and the share of dairy cattle in milk production displayed a rapid increase.

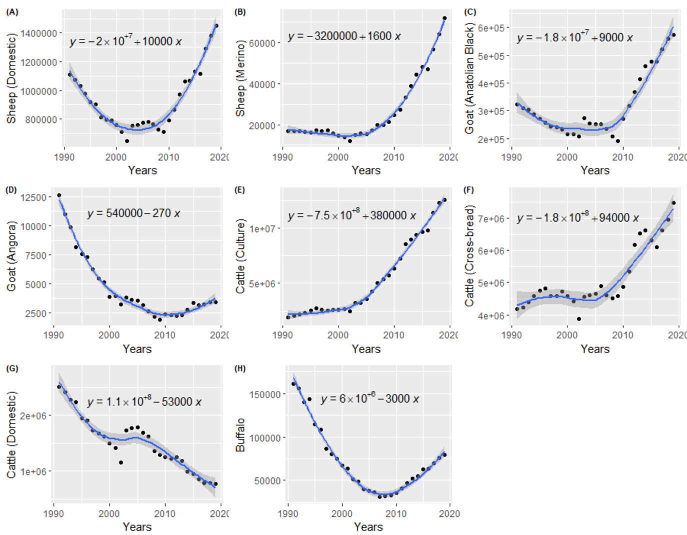

FIGURE 3. Time series and trend curves for species-based milk production

In the ST curves given in FIG. 4, the data points for Cattle, Buffalo, Sheep, Goat, and Chicken meat production, as well as egg production are accumulated on the upper side of the 1:1 line. Consequently, the increasing trends observed in the time series of Cattle, Buffalo, Sheep, Goat, and Chicken meat production, as well as egg production according to the ST method.

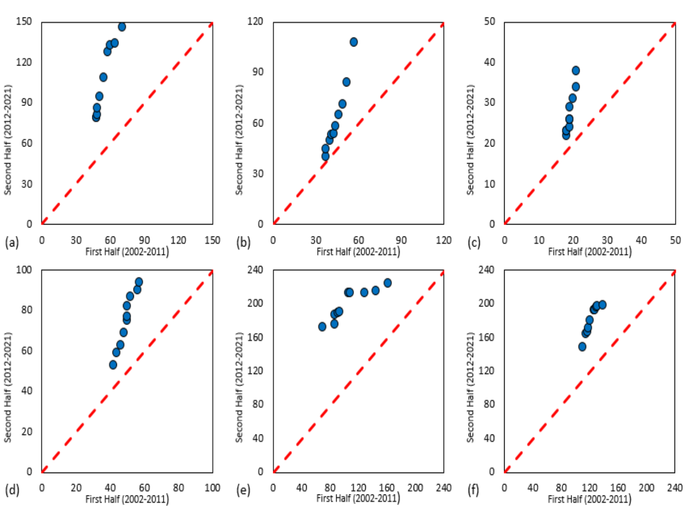

FIGURE 4. ST curves for red meat, white meat, egg production
a) Cattle x10⁴, b) Buffalo x10², c) Sheep x10⁴, d) Goat x10³, e) Chicken x10⁴, f) Egg x10⁵

In the ST curves for milk production given in FIG. 5, increasing trends were observed in Sheep (Merino), Sheep (Domestic), Goat (Anatolian Black), Cattle (Culture), and Cattle (Crossbred) milk production. On the contrary, decreasing trends were identified in Goat (Angora), Cattle (Domestic), and Buffalo milk production. According to the results of the ST method, the increasing trends in Sheep (Merino), Goat (Anatolian Black), Cattle (Culture), and Cattle (Crossbred) milk production were significant. Moreover, decreasing trends identified in Goat (Angora), Cattle (Domestic), and Buffalo milk production were also significant. However, the increasing trend in Sheep (Domestic) was not significant.

Erdal *et al.*, [41] examined the number of cattle, sheep, goat, and buffalo species in Türkiye between 1996 and 2014 using trend analysis. They determined a significant increase in the number of animals except for domestic cattle after 2004 with the Quadratic trend model. However, in the present study, meat and milk production parameters were considered instead of focusing only on animal count, and this methodology allowed determining more detailed trends. Due to the government incentives for crossbred and dairy cattle breeds, domestic cattle exhibited a downward trend. However, a similar decline has not been observed in domestic sheep breeds due to inadequate geographical conditions and insufficient government incentives for high-yielding sheep breeds. Sevinç *et al.*, [42] examined the number of sheep and goat in Turkiye between 2002 and 2021 using the Linear trend method and reported statistically significant upward trends in both sheep and goat counts . Although the results of this study are consistent with the existing literature, it provides more detailed findings. Plus, the examination of time series for production parameters using various nonparametric trend analysis methods (MMK, ST, SR, WW, CS, RR), more objective findings were obtained.

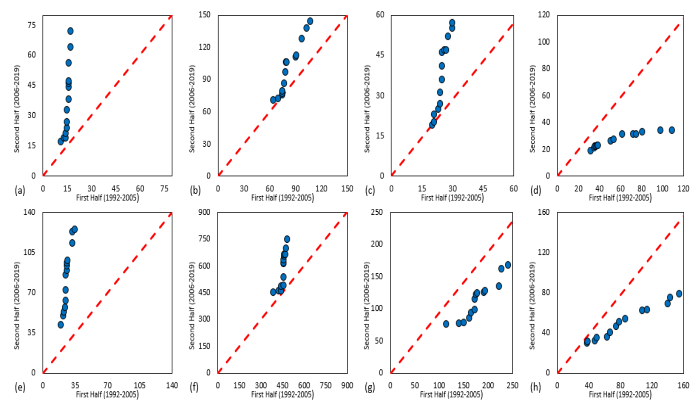

FIGURE 5. ST curves for milk production from Sheep (Merino), Sheep (Domestic), Goat (Anatolian Black), Goat (Angora), Cattle (Culture), Cattle (Crossbred), Cattle (Domestic), and Buffalo (a) Sheep (Merino) x10³, (b) Sheep (Domestic) x10⁴, (c) Goat (Anatolian Black), x10⁴, (d) Goat (Angora) x10², (e) Cattle (Culture) x10⁵, (f) Cattle (Crossbred) x10⁴, (g) Cattle (Domestic) x10⁴, (h) Buffalo x10³

CONCLUSIONS

As the world's population has grown rapidly, the demand for animal products has also increased. Therefore, Turkey, like other countries, supports producers with effective policies to meet the demand for animal products. As a result of these policies, the supply of animal products has increased to different levels over the years. However, animal production parameters in Turkiye have shown different levels of decrease due to various factors such as epidemics in certain periods, changes in consumption habits, and insufficient support and incentives. The increasing demand for staple foods such as milk, eggs, and red and white meat has led to breeding practices for specific animal species, including cattle, sheep, goats, and chickens. Consequently, species or breed-based annual production has shown significant changes.

Considering the supply of animal products by year, the rate of increase in the production of buffalo, sheep and goat meat was lower than in the production of beef, white meat and eggs. In addition, a decreasing trend was detected in the production of Cattle (Domestic), Goat (Angora) and Buffalo milk. Inadequate support for ovine breeding and the inability of high-productivity sheep and goat breeds to adapt to the country's conditions have resulted in this situation. In addition, although support and incentives for buffalo production have been increased, buffalo production has not reached the targeted levels due to drought and environmental conditions. In conclusion, the findings showed that annual chicken meat and egg production in Turkiye has significantly developed and now meets the demand in the country. However, it was found that the increase in red meat and milk production was insufficient to meet the growing demand and per capita consumption of animal products. To address these problems, it is recommended to increase support and incentives for animal production, expand cooperatives, eliminate the oligopoly market structure, and ensure that producers can sell their products at fair prices.

This study presents an exemplary methodology to the literature by evaluating production parameters based on both breed and species using multiple trend analysis methods. Future studies may examine products from animals with different economic values using these and other trend analysis methods. Accordingly, it can be determined how government incentives and supports contribute to production indicators on an annual basis.

Conflict of interest

Authors declare that they have no conflict of interest.

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