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Agricultural Mechanization Level and Projection Estimation of Soil Tillage Equipment's, Drills -Fertilizer Distributors of TR22 Region

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Abstract: In this study, the change in agricultural mechanization level of Balıkesir and Çanakkale provinces (TR22 Region) for the last 10 years (2013-2022) was determined, and the projection estimation of soil tillage equipment, drills and fertilizer distributors was determined. The material of the study consisted of tillage equipment, drills-fertilizing machines, two-axle tractors, and total cultivated area data obtained from the Turkish Statistical Institute (TUIK). For Balıkesir and Çanakkale provinces, the level of agricultural mechanization tended to increase according to the measured parameters between the years 2013-2022, and increases were observed in the number of soil tillage equipment and drills-fertilizer distributors. According to the projection coefficient values, tractor power values are generally projected to increase between 2023-2032 in Balıkesir and Çanakkale provinces. While the number of tractors increased in both provinces, the tractor power per unit cultivated area (kW ha^{-1}) and the number of tractors per 1000 hectares (tractor 1000 ha^{-1}) increased over the years, while the cultivated area per unit tractor (ha $tractor^{-1}$) also decreased in value. These findings show that there is an improvement in agricultural mechanization level in Balıkesir and Çanakkale provinces.

Keywords: Tractor, Cultivated area, Mechanization level, Projection coefficient, Çanakkale, Balıkesir.

TR22 Bölgesinin Tarımsal Mekanizasyon Seviyesi ile Toprak İşleme ile Ekim ve Gübreleme Makinaları Projeksiyon Tahmini

Öz: Bu çalışmada, Balıkesir ve Çanakkale illerinin (TR22 Bölgesi) son 10 yıla ait (2013-2022) tarımsal mekanizasyon seviyesindeki değişimi belirlenmiş, toprak işleme ile ekim ve gübreleme makinaları projeksiyon tahmini belirlenmiştir. Çalışmanın materyalini Türkiye İstatistik Kurumu'ndan (TÜİK) alınan toprak işleme ile ekim ve gübreleme makinaları, iki akslı traktörler verileri ve toplam işlenen alan verileri oluşturmuştur. Balıkesir ve Çanakkale illerinde için, 2013-2022 yılları arasında tarımsal mekanizasyon seviyesi ise ölçülen parametrelere göre artış eğiliminde olup, toprak işleme ekipmanları ve ekim makinaları sayısında da artışlar görülmüştür. Projeksiyon katsayısı değerlerine göre, Balıkesir ve Çanakkale illerinde 2023-2032 yılları arasında traktör gücü değerlerinin genel olarak artacağı öngörülmektedir. Her iki ilde de traktör sayılarında artış görülürken, birim işlenen alana düşen traktör gücü (kW ha^{-1}) ve 1000 hektar alana düşen traktör sayısı (traktör 1000 ha^{-1}) değerleri yıllara göre artış gösterirken, birim traktöre düşen işlenen alan (ha $traktör^{-1}$) değerinde de azalışlar olmuştur. Bu bulgular, Balıkesir ve Çanakkale illerinde tarımsal mekanizasyon seviyesinde bir iyileşme olduğunu göstermektedir. Çalışma sonuçlarına göre, Çanakkale ve Balıkesir illerinde tarımsal mekanizasyonun artmasıyla, tarımsal faaliyetlerinin ve teknolojilerinin verimliliği artırma potansiyeline sahip olduğunu göstermiştir.

Anahtar Kelimeler: Traktör, İşlenen alan, Mekanizasyon seviyesi, Projeksiyon katsayısı, Çanakkale, Balıkesir

1. Introductıon

In line with the productivity and sustainability goals of the agricultural sector, the importance of agricultural mechanization is increasing day by day (Smith et al., 2020). Therefore, increasing the level of agricultural mechanization and the use of appropriate agricultural equipment provide an important transformation in modern agriculture. Agricultural mechanization aims to increase productivity through the use of technology in agricultural processes. In this way, it is possible to carry out agricultural activities more effectively and use resources more sustainably.

The selection and use of appropriate equipment and machinery influences important factors such as

productivity, production quality, and environmental sustainability in the agricultural sector. The impact of agricultural mechanization has the potential to shape future farming technologies as well as provide farmers with better practices. The projection of soil tillage equipment and drills -fertilizer distributors is an approach that aims to increase the use of technology and efficiency of agricultural operations (Johnson et al., 2018). Studies on this topic related to agricultural mechanization provide significant benefits in the agricultural sector (Chen et al., 2021).

Demir and Kuş (2016) reported that the projection on the use of agricultural technology in the Central Anatolia Region for the next 10 years was examined. They explained that these projections include the use of agricultural equipment such as combine drills, chemical fertilizer distributors, harrows, pneumatic drills, and disc ploughs. Malaslı et al. (2015) reported that estimating future mechanization projections is of great importance in terms of determining the use of machinery and creating future scenarios to guide the relevant policies. Altuntaş (2020) calculated projection coefficients for the period until 2030 based on the 11-year production and utilization amounts of agricultural tools and machinery commonly used in agricultural production in Turkey. For this purpose, the projection coefficients in 5 different groups, such as tillage, drills, fertilizer and maintenance equipment's, spraying, harvesting, and other agricultural machinery, were determined and estimated the future trends and usage amounts of agricultural mechanization in Turkey. Gül et al. (2022) examined the use of tillage and drills and the projection estimation of the agricultural mechanization level in agricultural farmers among Tokat province.

In this study, the change in the level of agricultural mechanization in Balıkesir and Çanakkale provinces (TR22 Region) for the last 10 years (2013-2022) was determined, and the projection of the use of tillage equipment, drills, and fertilizer distributors was tried to be determined. By knowing the level of mechanization in the agricultural sector, important steps will be taken to achieve productivity and sustainability targets. Determining the use and projection of mechanization in the agricultural sector has the potential to shape the future agricultural policies of farmers, agricultural machinery manufacturers, and the ministry of agricultural as stakeholders.

The TR22 Region has a special position in terms of agricultural production compared to other regions in Turkey. The TR22 Region covers the South Marmara Region of Turkey and is a region with high agricultural potential. This region is favorable for the cultivation of various agricultural products due to its climate and geographical characteristics. The TR22 region has an area of 2 426 504 hectares, which corresponds to 3.1% of Turkey's total surface area. It is seen that 75.7% of the cultivable land consists of arable land (including fallow), 6.1% of vegetable land (including under cover), 7% of fruit land, 1.4% of vineyard land, and 9.9% of olive groves (Anonymous, 2023).

As the agricultural sector, grain production, fruit and vegetable production, and animal husbandry play an important role in TR22 Region provinces, especially grain production, which is of great importance in Balıkesir and Çanakkale provinces (Anonymous, 2023). However, the TR22 Region may also face some challenges in agricultural production. Factors affecting agricultural production in the region include insufficient water resources, the need to improve irrigation infrastructure, and soil fertility problems in some regions. At the same time, soil fertility problems in some regions can also negatively affect agricultural production (ZMO, 2020). However, TR22 Region is a region with agricultural potential, and it is possible to develop more efficient and sustainable agricultural practices with the right strategies, technological developments, and investments (Anonymous, 2013).

Machinery used in agricultural production depends on many factors affecting crop yield. These include machine capacity, tractor or agricultural machinery compatibility, land conditions, parcel size, soil and climate characteristics, crop pattern, production techniques, and trained manpower (Yıldız and Erkmen, 2004). Studies to determine the projection of tillage machines, drills, and fertilizer distributors can contribute to the development of policies on agricultural productivity. And also, the correct use of mechanization in the agricultural sector, the development of new technologies with the selection of appropriate equipment, and the benefits of the use of precision drill systems in agricultural production.

In this study, the change in the level of agricultural mechanization in Balıkesir and Çanakkale provinces (TR22 Region) for the last 10 years (2013-2022) was determined, and the projection of the use of tillage, drills, and fertilization machines was tried to be determined.

2. Material and Method

This study was conducted using the data on agricultural machinery from the Turkish Statistical Institute for the last 10 years, 2013-2022. These data

were analyzed based on the production and usage amounts for the TR22 region. The percentage increase and decrease values of the numbers obtained were calculated, and the average coefficients of these percentage changes were found. The South Marmara Region consisting of Balıkesir (TR221) and Çanakkale (TR222) provinces, is called TR22 Level 2 Region (GMKA, 2023). Balıkesir Province is situated in the southeastern part of the Marmara Region. It has a coastline along the Aegean Sea. In contrast, Çanakkale Province is located in the southern part of the Marmara Region, with coastlines along both the Aegean and Marmara Seas. Both provinces are located within the Marmara Region and are influenced by the Mediterranean climate, they have highly fertile areas for agriculture. Balıkesir Province, being closer to the Aegean Region, it has the agricultural products typical of the Aegean area. On the other hand, Çanakkale Province has more characteristics of the Marmara Region in its agricultural practices. Çanakkale Province holds a strategic position due to its location along the route of the Dardanelles Strait, making it essential for transportation and trade. In contrast, Balıkesir Province is situated further inland and does not have the same maritime significance (Anonymous, 2023a).

Table 1. Soil cultivation, drills and fertilization machinery used in calculations.
Çizelge 1. *Hesaplamalarda kullanılan toprak işleme, ekim ve gübreleme makinaları.*

Mouldboard plough	Toothed harrow
Stubble plough	Lister
Cultivator	Roller
Combined harrows	Earth auger
Horizontal axis rotary cultivators	Chemical fertilizer distributors
Vertical axes Rotary cultivators	Direct seed drills
Subsoiler	Combined seed drills
Disc Harrow	Pneumatic precision drills
Disc Stubble Plough (One way)	Trailed seed drills
Disc plough	Universal drills (including beet drills)

The agricultural mechanization level of Balıkesir and Çanakkale provinces was determined by the chain index method using data for the period 2013-2022 (Gül et al., 2022). The projection coefficient expresses the change in the number of existing machine. A positive (+) projection coefficient indicates that the number of existing tools and machinery has increased, while a negative (-) projection coefficient indicates that the number of existing tools and machinery has decreased (Demir et al., 2013). In this study, the change in the agricultural mechanization level of Balıkesir and Çanakkale provinces for the last 10 years (2013-2022) was determined, and the projection of tillage equipment and drills and fertilizer distributor usage was determined.

In the projection calculations in this study, the machines listed in Table 1 were considered, while in Table 2, tractors are divided into six groups according to their power values, and the average power values given in the calculation of the total power value are given (Kuzu et al., 2021).

Table 2. Average power groups of two axle tractors*
Çizelge 2. *İki akslı traktörlerin ortalama güç grupları**

Tractor powers groups (HP)	Average power of groups (HP)
> 70	85.5
51-70	60.5
35-50	42.5
25-34	29.5
11-24	17.5
1-10	5.5

*(Kuzu et al., 2021)

To indicate the average power values of the tractor groups, HP unit is used. Each tractor group has a certain power range, and these power values are given as average in Table 2. The mechanization level in Balıkesir and Çanakkale provinces has been assessed according to certain criteria for each year from 2013 to 2022, including the last 10 years. This assessment is based on total cultivated area, total tractor power and number of tractors. The criteria used to determine the mechanization level of the region are as follows:

a) Average tractor power (kW),

b) Number of tractors per unit agricultural area (tractor 1000 ha^{-1}),

c) Agricultural area per tractor (ha $tractor^{-1}$),

d) Tractor power per cultivated area (kW ha^{-1}).

The level of mechanization in Balıkesir and Çanakkale provinces was determined for each year by using these criteria.

3. Results and Discussion

Table 3 presents the total cultivated area of Balıkesir and Çanakkale provinces, which include the TR22 region, and the change in the last 10 years (2013-2022) and the projection estimates for the next 10 years (2023-2032). In Table 3, based on the projection coefficients, it is seen that the total cultivated area of Balıkesir province decreased by 7.80% and that of Çanakkale province increased by 7.82% between 2013 and 2022. According to the same projection coefficients, Balıkesir province is assumed to decrease by 7.73% and Çanakkale province is assumed to increase by 7.86% by 2022.

The number of tractors in TR22 provinces for the years 2013-2022 and the estimated number of tractors for the years 2023-2032 are given in Tables 4 and 5. In 2013, the number of 1-10 HP tractors, the lowest power group, was 290, while the number of more than 70 HP tractors, the highest power group, was 2770. In 2022, the number of 1-10 HP tractors increased to 507 and the number of more than 70 HP tractors to 5706. According to projection coefficients, increases in tractor assets are expected in Balıkesir province in the 2023-2032 period. In this period, the increase in >70 HP tractors, which is the highest power group, was higher compared with other groups. In 2022, the number of 35-50 HP and 51-70 HP tractors is observed to be higher with 32564 and 17543, respectively. According to the projection estimation in 2032, the number of 1-10 HP tractors is expected to reach 1081 and the number of more than 70 HP tractors is expected to reach 14435.

For Çanakkale province, while there was a decrease in 1-10 HP power groups between 2013- 2022, there was an increase in 11-24 HP, 25-34 HP, 35-50 HP, 51-70 HP and more than 70 HP groups. In 2013, the number of tractors in the lowest power group of 1-10 HP was 94, while the number of tractors in the highest power group of more than 70 HP was recorded as 2060. In 2022, while the number of 1-10 HP tractors was 74, the number of more than 70 HP tractors increased to 3933.

According to the projection coefficients, increases are expected in tractor assets in Çanakkale province in the 2023-2032 period, except for 1-10 HP tractors. In this period, the rate of increase in more than 70 HP tractors, which is the highest power group, is estimated to be higher compared to other power groups. In 2032, according to the projection estimate, the number of 35-50 HP and 51-70 HP tractors is expected to reach 10566 and 13528, respectively, while the number of more than 70 HP tractors is expected to reach 8576. In general, according to the projection coefficient values, while an increase is expected in tractor power groups in Balıkesir in the 2023-2032 period, a decrease is expected in Çanakkale, especially in the 1-10 HP power group.

The mechanization level indicators calculated using the total number of tractors, tractor power, and area cultivated data in TR22 provinces, the values obtained for the years 2013-2022, and the estimated values for the years 2023-2032 are given in Tables 6 and 7.

According to the tractor power and mechanization level values of Balıkesir province for the period 2013-2022 and projection estimates covering the period 2023-2032, tractor power in the province has continuously increased. Mechanization level indicators such as kW ha^{-1}, tractor 1000 ha^{-1}, and ha/tractor values have changed throughout the period. In the period 2013-2022, total tractor power in Balıkesir increased from 1 450 094.80 kW in 2013 to 2 226 270.83 kW in 2022 due to an increase in total tractor power. Mechanization level indicators are expressed as average tractor power, kW ha^{-1}, tractor 1000 ha^{-1} and ha/tractor, and these values have varied throughout the period.

According to the projection coefficients, tractor power is projected to continue to increase in Balıkesir province in the 2023-2032 period. For example, tractor power is expected to reach 2 367 686.03 kW in 2023 and 4 121 346.68 kW in 2032. Mechanization level indicators also show an upward trend in general. Considering these data, it is seen that agricultural mechanization plays an important role in Balıkesir province and tractor power is continuously increasing. This can be considered as a positive development in terms of increasing technology use and productivity in the agricultural sector.

The tractor power and mechanization level indicators of Çanakkale province obtained between 2013 and 2022 and the values estimated for 2023-2032 are shown in Table 7.

Table 3. The cultivated areas according to the provinces of the TR22 region and the 2023-2032 projection.
Çizelge 3. *TR22 bölgesi illerine göre işlenen alanlar ve 2023-2032 projeksiyonu.*

Years	Balıkesir	Çanakkale
	Total cultivated area (ha)	**Total cultivated area (ha)**
2013	423 931.58	278 723.90
2014	420 758.56	284 373.00
2015	411 122.86	287 954.10
2016	413 125.27	290 747.90
2017	407 126.27	288 898.20
2018	393 635.57	291 553.20
2019	388 024.87	292 515.90
2020	390 253.55	297 206.20
2021	391 123.65	302 173.20
2022	390 873.25	300 520.40
Projection Coefficient	-0.007	0.008
2023	387 394.79	303 057.13
2024	383 947.28	305 615.27
2025	380 530.45	308 195.00
2026	377 144.03	310 796.51
2027	373 787.75	313 419.98
2028	370 461.33	316 065.60
2029	367 164.52	318 733.55
2030	363 897.05	321 424.01
2031	360 658.65	324 137.19
2032	357 449.08	326 873.27

Table 4. The tractor inventory and the change between 2013-2022, as well as the projected estimation for 2023-2032 based on the power groups in Balıkesir province.
Çizelge 4. *Balıkesir ilinin güç gruplarına göre traktör varlığı ve 2013-2022 değişimi, 2023-2032 projeksiyon tahmini.*

Years	Tractor power groups HP					
	1-10	11-24	25-34	35-50	51-70	>70
2013	290	814	1527	23468	11182	2770
2014	314	813	1501	22902	11344	2821
2015	320	793	1480	21896	11511	3047
2016	331	782	1508	21813	12005	3124
2017	329	778	1503	21714	12118	3173
2018	330	782	1488	21582	12222	3276
2019	327	777	1488	21446	12268	3327
2020	535	1260	2435	34744	20062	5472
2021	506	1253	2395	34104	19453	5436
2022	507	1235	2376	32564	17543	5706
Projection Coefficient	0.079	0.062	0.065	0.052	0.067	0.097
2023	547	1311	2531	34256	18714	6261
2024	590	1392	2696	36037	19963	6870
2025	636	1478	2872	37910	21295	7538
2026	686	1569	3059	39880	22716	8271
2027	740	1666	3258	41952	24232	9076
2028	799	1769	3471	44133	25850	9958
2029	861	1878	3697	46426	27575	10927
2030	929	1994	3938	48839	29415	11990
2031	1002	2117	4194	51377	31378	13156
2032	1081	2248	4468	54047	33472	14435

Table 5. The tractor inventory and the change between 2013-2022, as well as the projected estimation for 2023-2032 based on the power groups in Çanakkale province.
Çizelge 5. *Çanakkale ilinin güç gruplarına göre traktör varlığı ve 2013-2022 değişimi, 2023-2032 projeksiyon tahmini.*

Years	Tractor power groups HP					
	1-10	11-24	25-34	35-50	51-70	>70
2013	94	236	1591	9316	9441	2060
2014	76	248	1582	8966	9683	2939
2015	74	257	1589	9068	10219	3294
2016	74	257	1588	9094	10722	3495
2017	73	257	1588	9101	10874	3632
2018	66	261	1594	9450	10775	3522
2019	66	266	1609	9494	10696	3702
2020	70	282	1660	9679	10862	3794
2021	71	281	1638	9765	11005	3837
2022	74	279	1616	9880	11184	3933
Projection Coefficient	-0.023	0.019	0.002	0.007	0.019	0.081
2023	72	284	1619	9947	11399	4252
2024	71	290	1622	10013	11618	4597
2025	69	295	1625	10081	11841	4969
2026	67	301	1628	10149	12069	5372
2027	66	307	1631	10217	12300	5808
2028	64	312	1634	10286	12537	6279
2029	63	318	1637	10355	12778	6788
2030	61	324	1640	10425	13023	7338
2031	60	331	1643	10495	13273	7933
2032	58	337	1646	10566	13528	8576

According to Table 7, tractor power in Çanakkale province has increased over the years and reached 1 092 075.70 kW in 2022. Looking at the mechanization level indicators, kW ha^{-1}, tractor 1000 ha^{-1} values have increased between 2013 and 2017, and the mechanization level indicators in 2022 is calculated as 3.63 kW ha^{-1}, 89.73 tractor 1000 ha^{-1} and 11.14 tractors per ha.

According to the projection coefficient values, tractor power and mechanization level values are generally projected to increase between 2023 and 2032 in Çanakkale province. For example, in 2032, tractor power is estimated to be 1 393 201.86 kW, as an indicator of the mechanization level, tractor power per

unit cultivated area will be 4.26 kw/ha, the number of tractors per 1000 ha agricultural area will be 99.81, and the unit cultivated area per tractor will be 10.03 ha/tractor. Based on these data, it is predicted that the use of tractors will increase in Çanakkale province and there will be improvements in the level of mechanization.

Table 6. The projection estimates covering the period of 2023-2032 for Balıkesir province include the tractor power and mechanization level values from 2013-2022.
Çizelge 6. *Balıkesir ilinin 2013-2022 dönemindeki traktör gücü ve mekanizasyon seviyesi değerleri ile 2023-2032 dönemini kapsayan projeksiyon tahminleri.*

Years	**Total Tractor power (kW)**	**Mechanization level indicators**			
		Average Tractor power (kW)	**kW ha^{-1}**	**tractor 1000 ha^{-1}**	**ha tractor^{-1}**
2013	1 450 094.80	36.21	3.42	94.48	10.58
2014	1 442 314.18	36.33	3.43	94.34	10.60
2015	1 431 731.97	36.67	3.48	94.98	10.53
2016	1 456 460.46	36.81	3.53	95.77	10.44
2017	1 461 292.67	36.89	3.59	97.30	10.28
2018	1 467 968.19	37.00	3.73	100.80	9.92
2019	1 468 876.42	37.06	3.79	102.14	9.79
2020	2 393 704.58	37.11	6.13	165.30	6.05
2021	2 343 239.63	37.11	5.99	161.45	6.19
2022	2 226 270.83	37.15	5.70	153.33	6.52
Projection Coefficient	0.064	0.003	0.072	0.069	-0.042
2023	2 367 686.03	37.25	6.11	163.95	6.24
2024	2 518 084.08	37.36	6.55	175.31	5.98
2025	2 678 035.57	37.47	7.02	187.46	5.73
2026	2 848 147.37	37.57	7.53	200.45	5.48
2027	3 029 064.85	37.68	8.07	214.34	5.25
2028	3 221 474.42	37.79	8.66	229.19	5.03
2029	3 426 106.05	37.90	9.28	245.08	4.81
2030	3 643 736.12	38.01	9.95	262.06	4.61
2031	3 875 190.28	38.11	10.67	280.22	4.41
2032	4 121 346,68	38,22	11,44	299,63	4,23

Table 7. The projection estimates covering the period of 2023-2032 for Çanakkale province include the tractor power and mechanization level values from 2013-2022.
Çizelge 7. *Çanakkale ilinin 2013-2022 dönemindeki traktör gücü ve mekanizasyon seviyesi değerleri ile 2023-2032 dönemini kapsayan projeksiyon tahminleri.*

Years	Total Tractor power (kW)	Mechanization level indicators			
		Average Tractor power (kW)	kW ha^{-1}	tractor 1000 ha^{-1}	ha tractor^{-1}
2013	878 630.91	38.64	3.15	81.58	12.26
2014	933 335.22	39.73	3.28	82.62	12.10
2015	982 861.39	40.12	3.41	85.09	11.75
2016	1 018 625.10	40.37	3.50	86.78	11.52
2017	1 034 178.99	40.52	3.58	88.35	11.32
2018	1 033 959.30	40.28	3.55	88.04	11.36
2019	1 043 468.78	40.39	3.57	88.31	11.32
2020	1 063 732.34	40.37	3.58	88.65	11.28
2021	1 074 993.50	40.42	3.56	88.02	11.36
2022	1 092 075.70	40.50	3.63	89.73	11.14
Projection Coefficient	0.025	0.005	0.016	0.011	-0.010
2023	1 118 996.87	40.71	3.69	90.69	11.03
2024	1 146 581.69	40.93	3.75	91.66	10.91
2025	1 174 846.52	41.14	3.81	92.64	10.80
2026	1 203 808.11	41.36	3.87	93.64	10.69
2027	1 233 483.64	41.58	3.94	94.64	10.57
2028	1 263 890.72	41.80	4.00	95.65	10.46
2029	1 295 047.37	42.02	4.06	96.68	10.35
2030	1 326 972.08	42.24	4.13	97.71	10.25
2031	1 359 683.78	42.46	4.19	98.76	10.14
2032	1 393 201.86	42.68	4.26	99.81	10.03

Table 8. The numbers (quantities) of soil tillage machinery in Balıkesir province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 8. *Balıkesir ilinin 2013-2022 dönemindeki toprak işleme makinaları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Lister	Subsoiler	Disc stubble Plough (One-way)	Disc Harrow	Disc plough	Toothed Harrow	Combined harrow
2013	1321	1472	370	3876	442	11135	555
2014	1326	1499	377	3764	459	11156	551
2015	1322	1561	378	3676	480	11093	553
2016	1371	1594	376	3753	499	11152	555
2017	1378	1608	379	3744	502	11187	558
2018	1387	1625	388	3780	520	11231	574
2019	1407	1628	388	3797	542	11226	569
2020	1420	1671	408	3787	549	11243	603
2021	1465	1725	406	3903	569	11268	635
2022	1466	1667	406	3928	579	11122	647
Projection Coefficient	0.012	0.014	0.011	0.002	0.031	0.000	0.017
2023	1483	1691	410	3934	597	11121	658
2024	1501	1714	415	3941	615	11119	670
2025	1518	1739	419	3947	634	11118	681
2026	1536	1763	423	3954	653	11117	693
2027	1554	1788	428	3960	673	11116	705
2028	1572	1813	432	3967	694	11114	718
2029	1591	1839	437	3973	715	11113	730
2030	1609	1865	441	3980	737	11112	743
2031	1628	1891	446	3986	759	11110	756
2032	1647	1918	451	3993	782	11109	769

Table 8 (Continue). The numbers (quantities) of soil tillage machinery in Balıkesir province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 8 (Devamı). *Balıkesir ilinin 2013-2022 dönemindeki toprak işleme makinaları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Mouldboard Stubble plough	Mouldboard plough	Cultivator	Roller	Earth auger	Horizontal axis rotary cultivators	Vertical axis Rotary cultivators
2013	1074	37344	19611	477	89	175	993
2014	1082	36893	19672	462	89	178	1072
2015	1179	36264	19598	480	92	207	1130
2016	1175	36308	19820	494	92	286	1175
2017	1209	35597	19829	502	100	291	1232
2018	1213	35794	19949	519	103	302	1249
2019	1214	35968	20115	546	110	309	1276
2020	1623	36197	20187	559	117	329	1310
2021	1642	36974	20649	588	126	348	1396
2022	1545	37014	20893	616	148	354	1486
Projection Coefficient	0.046	-0.001	0.007	0.029	0.059	0.087	0.046
2023	1616	36980	21041	634	157	385	1554
2024	1691	36947	21190	652	166	418	1626
2025	1769	36913	21340	671	176	454	1701
2026	1851	36880	21492	691	186	494	1779
2027	1937	36846	21644	711	197	536	1861
2028	2027	36812	21797	732	209	583	1947
2029	2120	36779	21952	753	222	633	2036
2030	2218	36746	22107	775	235	688	2130
2031	2321	36712	22264	798	249	748	2228
2032	2428	36679	22422	821	263	813	2330

The current status of the number of tillage machines used in TR22 provinces for the years 2013- 2022 and the estimated values for the next 10 years for the years 2023-2032 are given in Tables 8 and 9. According to Table 8, the fact that the number of soil tillage machines in Balıkesir province increased slightly in 2022 (81871) compared to 2013 (78934) shows the efficiency of soil tillage activities in agricultural production. Among the tillage equipment used in the agricultural sector in Balıkesir, the ones with the highest rate of increase are disc plough, soil auger, mouldboard tractor plough, and horizontal axis rotary cultivators. These equipments cover the equipment used for primary tillage in agricultural lands. There are small decreases in the number of mouldboard ploughs, while there is a noticeable increase in other equipment in general.

Table 9 shows a significant increase in the number of tillage machines in Çanakkale province in 2022 (64043) compared with 2013 (62874). For Çanakkale province in general, among the increases in the use of many tillage equipment between 2013 and 2022, significant increases were recorded especially in equipment such as mouldboard plough, cultivator and disc harrow. Although the number of mouldboard ploughs is the highest in Çanakkale province according to 2022 data, when the change between 2013 and 2022 is analyzed, fluctuations and partial decreases are observed, while there is a large increase in equipment such as subsoilers, mouldboard stubble ploughs, and Horizontal axis rotary cultivators. The number of subsoilers increased from 421 in 2013 to 1064 in 2022, an increase of 152.02%. This shows that the use of subsoilers has increased in agricultural lands in order to prevent the formation of soil stones, increase soil fertility and ensure healthier development of plant roots. Mouldboard stubble plough increased by 400% from 32 units in 2013 to 160 units in 2022. Stubble plough increases organic matter content and improves the soil structure by mixing plant residues left in the field into the soil. The increasing number of mouldboard stubble ploughs is the result of the adoption of sustainable agricultural practices and efforts to increase soil fertility. Horizontal axis rotary cultivators increased by 584.75%, from 59 in 2013 to 403 in 2022. Horizontal axis rotary cultivators aerate the soil, help plant roots to develop better and facilitate the soil preparation process. These increases agree with the goals of increasing productivity in agricultural activities, improving soil fertility, and transition to sustainable agricultural methods. In the study by Malaslı et al. (2015), there was a significant increase in the number of second-class tillage implements, indicating that farmers in the region have an increasing awareness of soil conservation.

Table 9. The numbers (quantities) of soil tillage equipments in Çanakkale province for the period of 2013-2022 and the projection for the years 2023-2032.
Çizelge 9. *Çanakkale ilinin 2013-2022 dönemindeki toprak işleme ekipmanları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Lister	Subsoiler	Disc stubble plough (One-way)	Disc Harrow	Disc Plough	Toothed Harrow	Combined harrow
2013	1033	421	571	8637	671	11009	87
2014	962	988	700	8368	709	10819	260
2015	970	1004	709	8455	707	10995	279
2016	1007	1021	723	8635	707	11146	285
2017	1013	1033	724	8701	715	11255	288
2018	1006	1032	736	8653	720	11394	284
2019	1008	1043	752	8660	693	11451	299
2020	1010	1034	758	8560	698	11453	306
2021	1012	1036	757	8479	711	11681	313
2022	1005	1064	772	8491	699	11682	326
Projection Coefficient	-0.003	0.158	0.036	-0.002	0.005	0.0067	0.247
2023	1002	1232	800	8476	702	11760	406
2024	1000	1427	829	8461	706	11838	507
2025	997	1652	859	8445	709	11917	632
2026	994	1913	890	8430	713	11997	788
2027	992	2215	922	8415	716	12077	982
2028	989	2565	955	8400	720	12157	1224
2029	986	2970	989	8385	723	12239	1526
2030	984	3440	1025	8370	727	12320	1903
2031	981	3983	1062	8355	730	12402	2372
2032	978	4612	1100	8340	734	12485	2957

Table 9 (Continue). The numbers (quantities) of soil tillage machinery in Çanakkale province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 9 (Devamı). *Çanakkale ilinin 2013-2022 dönemindeki toprak işleme makinaları sayıları (adet) ve 2023-2032 yılları için projeksiyonu.*

Years	Moulboard Stubble plough	Mouldboard plough	Cultivator	Roller	Earth auger	Horizontal axis rotary cultivators	Vertical axis Rotary cultivators
2013	32	29458	9497	850	130	59	419
2014	126	27865	9367	826	124	299	540
2015	130	27997	9486	841	129	321	572
2016	127	28113	9614	857	132	343	598
2017	126	28226	9676	846	141	375	651
2018	127	27947	9636	865	174	379	674
2019	132	27602	9739	891	189	380	721
2020	139	27587	9838	916	230	387	745
2021	142	27473	10182	936	240	394	771
2022	160	27275	10189	942	245	403	790
Projection Coefficient	0.354	-0.008	0.008	0.012	0.076	0.486	0.076
2023	217	27047	10270	953	264	599	850
2024	293	26821	10351	964	284	890	914
2025	397	26596	10433	975	306	1323	983
2026	538	26374	10516	987	329	1966	1057
2027	728	26153	10599	998	354	2922	1137
2028	986	25934	10683	1010	381	4343	1223
2029	1336	25717	10768	1022	410	6454	1315
2030	1809	25502	10853	1034	441	9593	1415
2031	2449	25289	10939	1046	475	14257	1522
2032	3316	25077	11026	1058	511	21188	1637

Table 10. The numbers (quantities) of drills and fertilizer distributors in Balıkesir province for the period of 2013-2022 and the projection for the years 2023-2032.

Çizelge 10. *Balıkesir ilinin 2013-2022 dönemindeki ekim makinaları ve gübre dağıtma sayıları (adet) ve 2023-2032 projeksiyonu.*

Years	Direct seed drills	Combined seed drills	Pneumatic precision drills	Trailed seed drills	Chemical fertilizer distributors	Universal seed drills (including beet drills)
2013	44	1945	350	2770	7744	1947
2014	44	1966	380	2797	7819	1953
2015	45	1971	402	2832	7989	1947
2016	46	2011	459	2825	9111	1649
2017	48	2023	469	2833	9178	1652
2018	55	2064	505	2838	9324	1654
2019	53	2092	524	2887	9395	1658
2020	54	2123	558	2929	9453	1683
2021	65	2151	633	2987	9453	1707
2022	86	2343	703	2815	9576	1685
Projection Coefficient	0.083	0.021	0.081	0.002	0.025	-0.015
2023	93	2393	760	2821	9812	1660
2024	101	2443	822	2827	10054	1636
2025	109	2495	889	2832	10302	1612
2026	118	2548	961	2838	10556	1589
2027	128	2602	1039	2844	10816	1566
2028	138	2657	1123	2850	11083	1543
2029	150	2713	1215	2856	11356	1520
2030	162	2771	1314	2861	11636	1498
2031	176	2830	1420	2867	11923	1476
2032	190	2890	1536	2873	12217	1455

It is observed that the number of drills and fertilizer distributors has increased over the years in Balıkesir province (Table 10). The number of stubble seeders increased from 44 to 86 between 2013 and 2022; the number of combined seed drills increased from 1945 to 2343; and the number of pneumatic precision drills increased from 350 to 703 between 2013 and trailed seed drills. This is an important indicator of productivity in agricultural areas and faster and more efficient sowing operations. According to 2023-2032 projection coefficients, the use of agricultural equipment in Balıkesir is expected to continue to increase in general.

Significant increases are expected, especially in the amount of equipment such as direct seed drills, combined seed drills, and pneumatic precision seedersTable 11 shows a certain increase and change in the use of drills and fertilizer distributors in Çanakkale province. A significant increase in the amount of equipment such as direct seed drills, combined seed drills, and pneumatic precision drills was observed. In particular, combined seed drills have great importance in grain sowing. In addition, pneumatic precision drills are preferred equipment due to their precise seed distribution. The increase in the number of this equipment reflects the trend toward more precise and effective seed sowing in agriculture.

Table 11. The numbers (quantities) of drills and fertilizer distributors in Çanakkale province for the period of 2013-2022 and the projection for the years 2023-2032.
Çizelge 11. *Çanakkale ilinin 2013-2022 dönemindeki ekim makinaları sayıları (adet) ve 2023-2032 projeksiyonu.*

Years	Direct seed drills	Combined seed drills	Pneumatic precision drills	Trailed seed drills	Chemical fertilizer distributors	Universal seed drills (including beet drills)
2013	1	3546	403	1897	9164	1675
2014	25	3669	460	1910	9541	1673
2015	26	3675	469	1913	9649	1677
2016	25	3690	496	1948	9824	1689
2017	25	3696	508	1969	9978	1693
2018	24	3722	530	1963	10060	1695
2019	23	3744	542	1976	10159	1694
2020	22	3771	555	1981	10145	1696
2021	20	3785	568	1981	10258	1688
2022	20	3863	571	1987	10248	1676
Projection Coefficient	2.643	0.010	0.040	0.005	0.013	0.0001
2023	73	3900	594	1997	10377	1676
2024	265	3938	618	2008	10507	1676
2025	967	3975	643	2018	10639	1676
2026	3 522	4014	668	2029	10773	1676
2027	12 830	4052	695	2039	10908	1677
2028	46 737	4091	723	2050	11046	1677
2029	170 256	4131	752	2060	11184	1677
2030	620 216	4170	782	2071	11325	1677
2031	2 259 341	4210	814	2082	11467	1677
2032	8 230 400	4251	846	2092	11611	1677

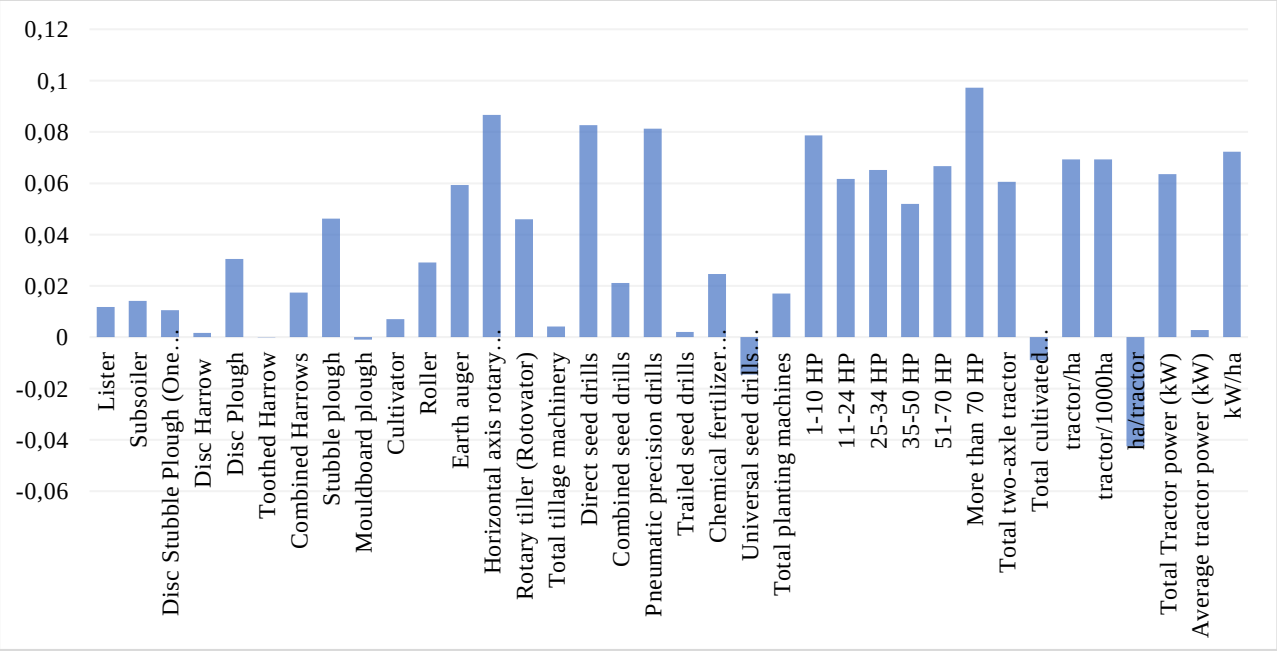

Figure 1. The change in the projection coefficients of two-axle tractors, indicators of agricultural mechanization level, and agricultural equipment machinery for Balıkesir province.
Şekil 1. *Balıkesir iline ait, iki akslı traktörler, tarımsal mekanizasyon düzeyi göstergeleri ile tarım alet makinalarının projeksiyon katsayıları değişimi.*

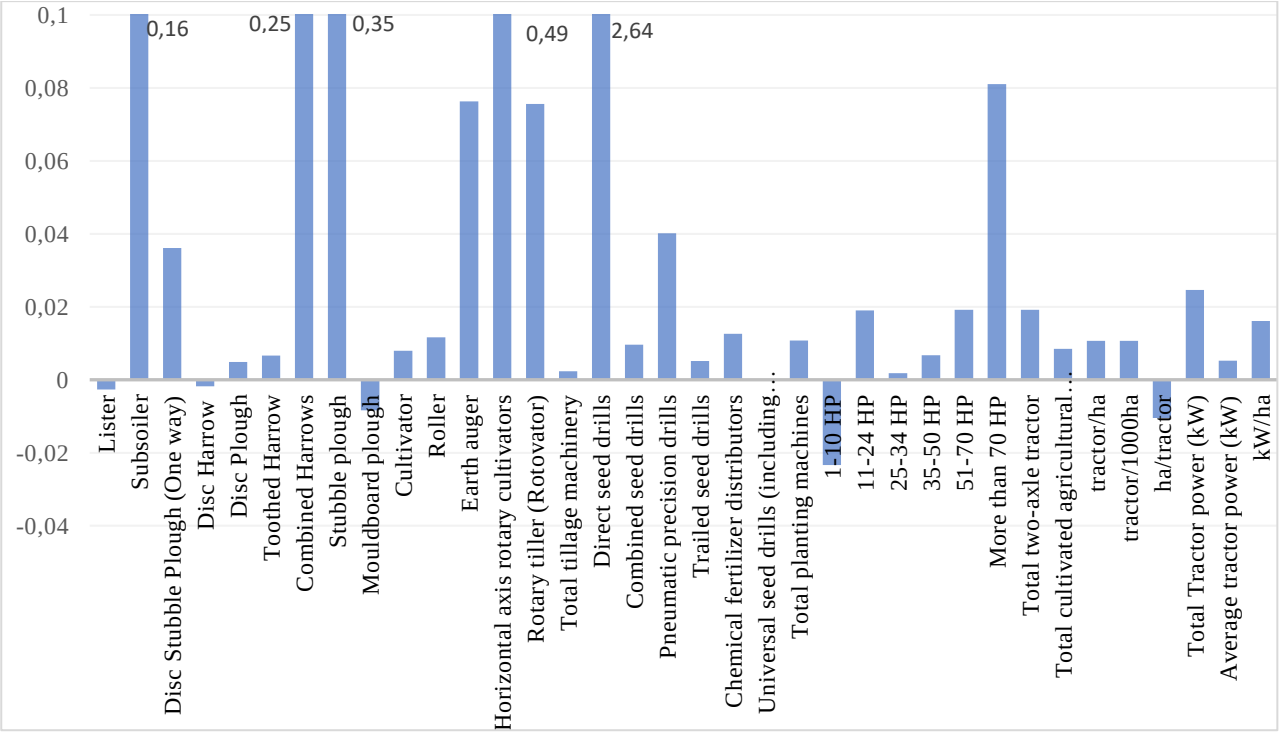

Figure 2. The change in the projection coefficients of two-axle tractors, indicators of agricultural mechanization level, and agricultural equipment machinery for Çanakkale province.
Şekil 2. *Çanakkale için iki akslı traktörlerin ve mekanizasyon düzeyi göstergeleri ile tarım alet makinalarının, projeksiyon katsayıları değişimi.*

In Çanakkale province, while the number of direct seed drills was 1 in 2013, it increased to 20 in 2022. In this period, an increase was observed in the use of broadcast seeding machines. The number of combined grain seeders increased from 3546 in 2013 to 3863 in 2022. This shows an increase in the amount of equipment used in grain cultivation. Increases were also observed in the number of pneumatic precision drills and trailed seed drills. In general, no significant change was observed in the number of universal seed drills, trailed seed drills.

For Çanakkale province, there is a general increase in the equipment used in agricultural practices such as sowing, fertilization, and other agricultural operations. These increases indicate that modern agricultural techniques and efficiency are being adopted and the agricultural sector is developing. This trend is expected to continue in the coming years.

In Figure 1 and Figure 2, the projection coefficients of two-axle tractors, mechanization level indicators, and agricultural machinery for Balıkesir and Çanakkale provinces are presented and compared together with their changes.

4. Conclusion

In this study, data obtained from the Turkish Statistical Institute (TUİK) were used to determine the agricultural mechanization level of Balıkesir and Çanakkale provinces. These data include important indicators such as the number of soil tillage equipment and drills-fertilizer distributors, cultivated area, and number of tractors.

In this study, we examined the change in the presence of tillage and drills and fertilizer distributors in Balıkesir and Çanakkale provinces during the last 10 years 2013-2022 and analyzed the number of tractors and agricultural mechanization level indicators.

The study made forecasts using projection coefficients for the next decade. These forecasts predict the expected change in the level of agricultural mechanization in Balıkesir and Çanakkale provinces. The results characterize the level of agricultural mechanization and its numerical change in the region. The use of tillage machinery, drills, and fertilizer distributors in the agricultural sector for TR22 provinces has a dynamic structure.

Analyses based on numerical data emphasize how equipment preferences in agricultural production have changed over time and the importance of supporting this change with agricultural policies. These data can be used as a guide in determining the future directions of the agricultural sector in Balıkesir and Çanakkale provinces. According to the findings of the study, agricultural mechanization in the TR22 region has made

significant progress between 2013 and 2022.

Moreover, increases were observed in indicators such as tractor power, average tractor power, and tractor power per hectare area. The increase in the number of soil tillage equipments, drills, and tractors indicates that agricultural mechanization in the region has improved technologically and productivity has increased. Future projections indicate that agricultural mechanization will further improve in the TR22 region.

The difference in the number of agricultural machinery between Balıkesir and Çanakkale provinces, in light of the economic difficulties that started in Turkey in 2018 and continued into 2019, can be attributed to several potential factors. Firstly, the types of crops grown in each region might differ, with Balıkesir possibly specializing in more resilient and diverse agricultural products, ensuring a continuous demand for machinery and thus maintaining stable numbers. Secondly, the size of agricultural operations could vary, with Balıkesir possibly hosting larger farms that tend to employ more mechanization, potentially preventing a decline in the number of agricultural machines. Additionally, differences in export opportunities, government policies and support, labor availability, and climate conditions might all play roles in influencing the resilience of the agricultural machinery sector in these two provinces. Further detailed analysis would be necessary to pinpoint the exact reasons for this disparity.

Estimates using the chain index method predict that the number of soil tillage equipment, drills, and tractors will continue to increase. This will make the agricultural production more efficient and sustainable. However, according to the results of the study, there are some challenges for further development of agricultural mechanization in the TR22 region.

Factors such as insufficient water resources, the improvement of irrigation infrastructure, and soil fertility problems may limit the effective use of agricultural mechanization. Therefore, strategic planning for the development of agricultural mechanization in the region requires technological investments and infrastructure development.

Finally, it has been shown that agricultural activities and technologies can increase productivity by increasing agricultural mechanization in Çanakkale and Balıkesir provinces. This will ensure the transition of farmers to more modern and effective agricultural equipment and methods and ensure sustainability.

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