# A case study on agricultural machinery variety and agricultural mechanisation level of Türkiye

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| ARTICLE INFO | ABSTRACT |
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| | In this study, the varieties of machinery used in agricultural applications and the characteristics of the level of agricultural mechanisation in Türkiye were investigated. All data used in the study were taken from Turkish Statistical Institute (TUIK), National Tractor distributors and Turkish General Directorate of Security published database. The number of tractors, number of agricultural implements and machinery, variety of agricultural machinery used in Türkiye were examined and indicators such as the ratio of cultivated agricultural area to tractor power (kW/ha), the number of tractors per 1000 hectares of cultivated agricultural area (tractor/1000 ha) and the cultivated agricultural area per tractor were used to determine the level of agricultural mechanisation. In this study, the linkages between tractor power and tractor density were analysed and the number of tractors entering and leaving the farmers' agricultural machinery park over the years were taken into account. It is concluded that tractor economic life and park renewal rate is an important criterion as an indicator of the level of agricultural mechanisation in Türkiye and suggestions for solutions to tractor park problems are given respectively. |

# Türkiye'nin tarım makinaları çeşitliliği ve tarımsal mekanizasyon düzeyine ilişkin bir örnek çalışma

| MAKALE BİLGİSİ | ÖZET |
|---|---|
| | Bu çalışmada, Türkiye'de tarımsal uygulamalarda kullanılan makine çeşitleri ve tarımsal mekanizasyon düzeyinin özellikleri araştırılmıştır. Çalışmada kullanılan tüm veriler Türkiye İstatistik Kurumu (TÜİK), Ulusal Traktör Bayiileri ve Emniyet Genel Müdürlüğü'nün yayınladığı veri tabanlarından alınmıştır. Türkiye'de kullanılan traktör sayısı, tarım alet ve makine sayısı, tarım makine çeşitleri incelenmiş ve ekili tarım alanının traktör gücüne oranı (kW/ha), 1000 hektar ekili tarım alanına düşen traktör sayısı (traktör/1000 ha) ve traktör başına düşen ekili tarım alanı gibi göstergeler tarımsal mekanizasyon düzeyini belirlemek için kullanılmıştır. Bu çalışmada, traktör gücü ile traktör yoğunluğu arasındaki bağlantılar incelenmiş ve çiftçilerin tarım makine parkına yıllar itibarıyla giren ve çıkan traktör sayıları dikkate alınmıştır. Türkiye'de tarımsal mekanizasyon düzeyinin bir göstergesi olarak traktör ekonomik ömrü ve park yenileme oranının önemli bir kriter olduğu sonucuna varılmış ve sırasıyla traktör parkı sorunlarına yönelik çözüm önerileri sunulmuştur. |

## 1. Introduction

Agricultural machines are used for many different applications, such as tillage, sowing, irrigation, harvesting, storage and processing. For example, tractors are power

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machines which used to drive agricultural machines for performing the basic tasks of agriculture. The developments on agriculture and increased productivity is critical for the growth of the world's population and satisfy the need for food. Agricultural machines play important role in modernizing agriculture and making it more efficient. By reducing human labour, increased productivity and enable more field work time can be achieved with these machines.

Global population growth and limited natural resources pose a major threat to all countries. Nowadays, factors such as pandemics, wars, conflicts and climate changes have once again emphasized the critical role of food in human life. The fact that countries that are producers of food and agricultural products have given priority to their own citizens and restricted the sales of these products has had the effect of leading countries that are suppliers to search for new product types and productivity enhancers. Unfortunately, in a country where agricultural land is shrinking, increasing crop production efficiency is of vital importance. In this context, increasing agricultural productivity involves improvements in two main elements: product efficiency and input costs. Agricultural mechanization offers significant benefits in agricultural activities by saving time, reducing human labour and energy costs at every production stage. Furthermore, mechanization plays an influential role on product quality and productivity. Therefore, increasing the level of agricultural mechanization should be among the priority strategic objectives of all countries (Özgüven et.al 2010).

Agriculture contribute to employment, exporting and the all other industries in Türkiye. The utilization rate of Türkiye's land vary depending on the characteristics of climate and landforms. Although high mountainous areas have a large area, the utilization of the land here is quite limited due to the high number of steep slopes. While 36% of country's land consists of cultivated and planted areas, 32% consists of meadows and pastures, 26% of forests and 6% of settlements and bare rocks unsuitable for agriculture. Nowadays, due to high technological mechanization methods and machines in agriculture, meadow and pasture areas have shrunk, while agricultural areas continue to expand.

The agricultural sector occupies an important place in Türkiye's economic projection. According to 2011 data, the sector employs approximately 6.1 million people and generates an income of USD 62.7 billion. Moreover, in 2014, Türkiye has been exported 1707 different types of agricultural products to 190 countries and the total value of these exports amounted to 18.7 billion dollars (Turkish Agriculture and Forestry Ministry-2023).

The decline in the number of people working in the agricultural sector has been in line with the increase in the labour force in the service and industrial sectors. While agricultural employment rate was 50.6% in 1980 it continuously dropped to 34.3% in 2003, 25.5% in 2011 and men employment rate %15.5 and women employment % 30.7 (Turkish Agriculture and Forestry Ministry-2023). Although the agricultural sector had a 42.8% rate in GNP in the early years of the Republic, this rate has declined over time from 36% in 1970 to 25% in 1980, 16% in 1990, 13.5% in 2000, 12.6% in 2003 and finally 8.1% in 2011. The percentage rate of agricultural products in imports has also

increased. Rate of change was 0.6% in 1980, 7.3% in 2011and %15.9 in 2023 (Turkish Exporter's Assembly-2023). In 2022, cereals and other vegetable crops (excluding fodder crops) increased by 14.6%, while fruits, beverages and spices increased by 7.7%. However, vegetables decreased by 0.5%. Thus, cereals and other crops produced 70.2 million tons, vegetables 31.6 million tons, and fruits, beverages and spices 26.8 million tons.

This study provides an overview of the types and importance of agricultural machinery. These machines contribute to the growth of the agricultural sector and increase food production. Agricultural machineries are indispensable tools to feed the world's population by ensuring that agricultural applications more efficient.

In this study, statistical sources for determining agricultural mechanisation levels compiled by the Turkish Statistical Institute (TurkStat) and relevant data provided by the Ministry of Agriculture and Forestry are included. These data contain information such as the values of cultivated area, number of tractors, harvesters and agricultural machinery throughout Türkiye and specific to geographical regions. Agricultural machinery types are analysed in detail under classification and their contribution to agricultural processes. A series of indicators were identified to assess the level of tractor-based mechanisation. These indicators include tractor power per unit area (kW/ha), number of tractors per unit area (number of tractors/1000 ha), agricultural area per tractor (ha/tractor) and average tractor power (kW). Among these indicators, tractor power per unit area (kW/ha) is the most widely used indicator to explain the current situation and to draw comparative conclusions. In addition, other criteria used to assess the level of tractor mechanisation include factors such as the number of agricultural machinery and implements per tractor, preferred energy sources in the agricultural sector, and the average duration of use of tractors.

## 2. Materials and Methods

In this study all materials supplied from public open governmental databases and related sector suppliers. Data are classified and then refined according to their trust ratios. Each data set analyzed and regroup according to sections which are used for determine mechanization level of Türkiye. Values according to tractor axle and horsepower distribution regrouped under some common ratios. Therefore tables are constructed according to these regrouped data set. Figures constructed for show relations mechanization parameter's variations among years.

## 3.Results and Discussion

### 3.1 Tractor park

A tractor park is an area where tractors, construction machinery or agricultural machinery used in industries such as agriculture or construction are stored and maintained. Such parks are used to carry out regular maintenance and repairs of tractors, refuelling and keeping machinery safe (Ağcı, 2002). Tractor parks are generally indispensable for agricultural enterprises, construction companies, forestry enterprises and similar industries. These parks play an important role in order to increase the efficiency and lifetime of construction machinery (Doğan, 2012) were given in Table 1.

**Table 1.** Türkiye Tractor Number Data for 2012-2022 period (TUIK, 2023).

**Number of Tractors between 2012-2022**

| Year | Total | One axle Horse power | | Two axle Horse power | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-5 | 5 + | 1-10 | 11-24 | 25-34 | 35-50 | 50+ | 51-70 [1] | 70+[1] |
| **2012** | **1 178 253** | 9 450 | 36 188 | 5 696 | 20 704 | 71 989 | 488 877 | - | 438 623 | 106 522 |
| **2013** | **1 213 560** | 10 889 | 42 476 | 5 937 | 20 153 | 71 165 | 493 462 | - | 451 292 | 118 000 |
| **2014** | **1 243 300** | 14 383 | 51 492 | 6 247 | 20 906 | 69 223 | 493 914 | - | 461 399 | 125 536 |
| **2015** | **1 260 358** | 14 856 | 54 604 | 6 252 | 21 181 | 68 074 | 491 828 | - | 468 060 | 135 297 |
| **2016** | **1 273 531** | 15 736 | 57 131 | 6 448 | 21 274 | 66 825 | 489 621 | - | 475 665 | 140 699 |
| **2017** | **1 306 736** | 16 589 | 59 061 | 6 432 | 20 527 | 65 866 | 492 343 | - | 493 660 | 152 133 |
| **2018** | **1 332 139** | 17 129 | 60 707 | 6 554 | 20 886 | 66 104 | 493 134 | - | 505 087 | 162 425 |
| **2019** | **1 354 912** | 17 512 | 62 178 | 6 589 | 20 513 | 65 496 | 495 375 | - | 513 035 | 174 105 |
| **2020** | **1 442 909** | 19 416 | 73 782 | 6 969 | 20 944 | 68 157 | 517 899 | - | 544 909 | 190 677 |
| **2021** | **1 481 461** | 20 517 | 79 658 | 6 853 | 20 841 | 68 730 | 523 718 | - | 555 536 | 205 488 |
| **2022** | **1 526 769** | 20 008 | 84 568 | 6 384 | 20 212 | 68 045 | 532 393 | - | 570 629 | 224 408 |

Analysing table 1 showed that, in 2012 total number of tractors was 1 178 253. This is summation of one axle and two axle tractors which are in diffrenet horsepower rates. Looking at one axle tractors according to horsepower distribution it is seen that highest interest locating at 5+ section and in two axle case highest interest seen on 35-50 horsepower section. When date comes to 2022 highest interests seen on 5+ horsepower section for one axle tractors and 51-70 horsepower section for two axle tractors while total tractor number was 1 526 769. Rate of change of tractor numbers is %29.5 in ten years. There was no significant change in one axle case but it is seen that highest interest section updated to 51-70 horsepower in two axle tractors. Tractor park renewed with higher powered tractors sothat power section upgraded (Işık (1988), Sümer et.al.(2004)).

### 3.2. *Quantitative and qualitative characteristics of tractor parks*

In order to compare the tractor data in Türkiye, it is very important to analyse 'Cumulative Tractor Sales Numbers', TURKSTAT statistics and National Police database records. According to the results of this comparison, TurkStat statistics and 'Cumulative Tractor Sales Numbers' data followed a harmonised course until 1988, but diverged in the following years.

On the other hand, a better agreement was observed between traffic records and 'Cumulative Tractor Sales Numbers'. it can be foreseen that traffic records may be a more reliable data source for the tractor park in Türkiye. At the end of 2020, the average age of Türkiye's tractor park, which was recorded as 1.946.806 units, was calculated as 25.3 years in Figure 1. Based on this data, it can be concluded that the mechanical life of tractors in Türkiye is 24 years at most. In the calculation of mechanical life, it is taken into consideration that according to the standards, the mechanical life of tractors is 10,000 hours until 2000 and 12,000 hours after 2000. It was also informed that tractors in Türkiye are used for an average of 500 hours per year and this average increases to 600 hours as the power level increases. It can be concluded that a large part of the

tractor park in Türkiye consists of tractors that have completed their mechanical life. This information shows that the tractor park needs to be updated and modernised. Moreover, it is important to monitor the tractor park with more reliable and up-to-date data, so National Police database records may be a more suitable source for this purpose (Koçtürk and Avcıoğlu, 2007).
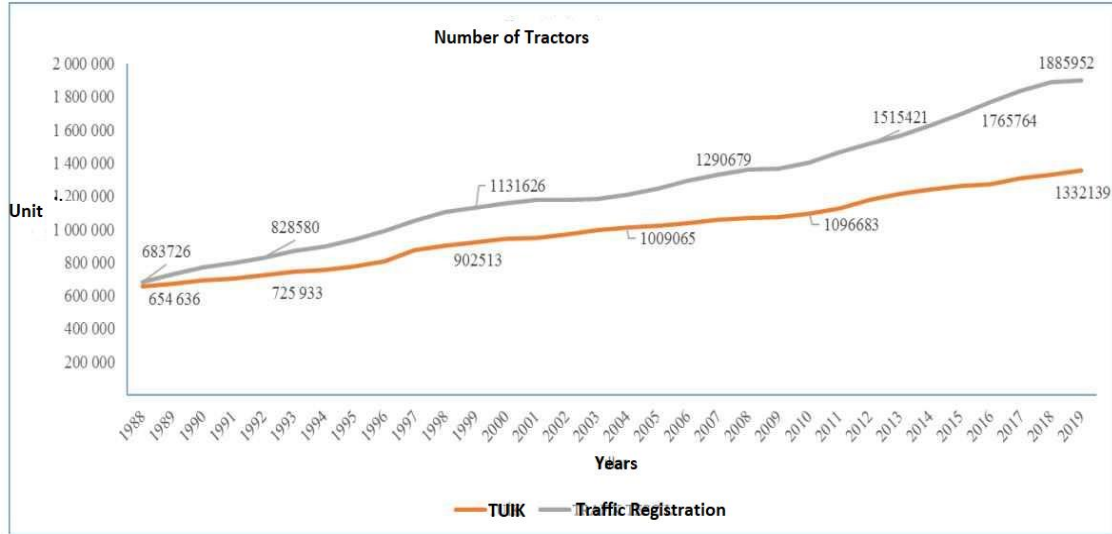


**Figure 1.** Development of Turkish Tractor park (TÜİK, 2020).

As seen in Figure 2, Although there are about 2 million tractors in Türkiye, about 500,000 of these tractors are over 40 years old. In addition, there are more than 150,000 tractors in the 35-39 age range. This situation further increases the importance of economic losses, environmental damage and safety deficiencies caused by the old tractor park. Moreover, in parallel with the development of the national economy and the agricultural sector, it is necessary to rapidly renew the old part of the existing tractor park. As of 2019, the average power of the tractor park in Türkiye was calculated as 39 kW (52.1 HP). This value is insufficient to utilise high production technologies and is far below the average of European countries (Tarmakbir, 2023).
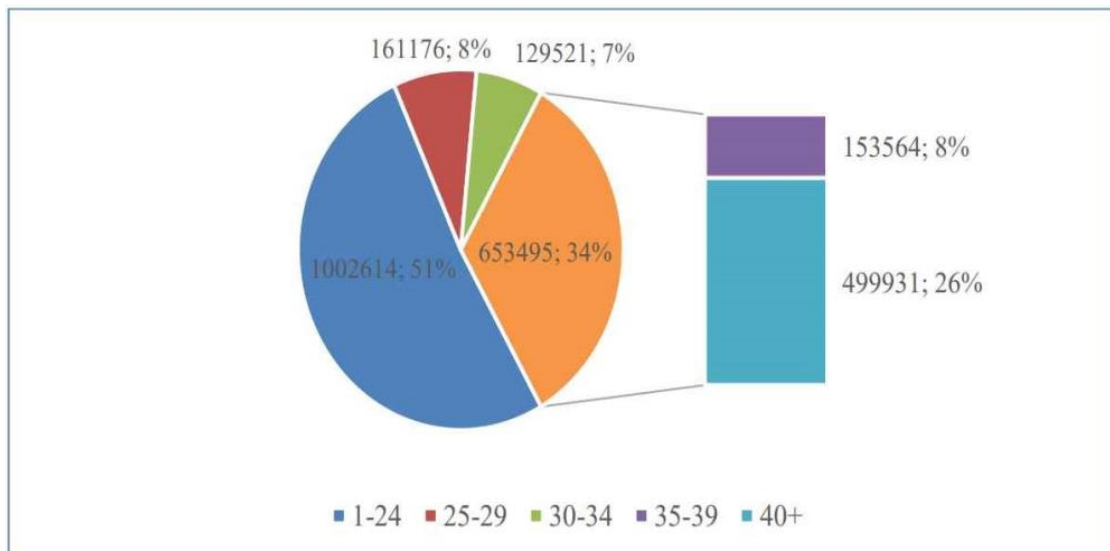


**Figure 2.** Distribution of tractor ages in Türkiye (TÜİK, 2020).

However, the difficulties of the agricultural enterprise structure appear to be the biggest barrier to this development. Therefore, both economic incentives for renewal and modernisation of the tractor park and policy changes may be needed to make the agricultural sector more efficient and competitive. In 2019, the majority of the tractor park in Türkiye consists of four-wheel tractors, which represent 94 per cent of the park. Single-axle tractors make up a very small part of the park (6 per cent). In the last five years, there has been a strong increase in the proportion of double-wheel drive tractors in tractor sales. This positive development indicates that the preference and use of double-wheel drive tractors are increasing. Double-wheel drive tractors can provide more ability to steering in agricultural work and may be more suitable for some applications. Continuation of this trend can increase agricultural productivity and contribute to the modernisation of the agricultural sector .(Evcim, et.al. 2010).

### 3.3. *Distribution of tractor parks by statistical regional units of Türkiye*

TurkStat's analysis of the number of tractors between 2016 and 2021 in Türkiye shows that the tractor park has increased in various regions of the country. However, in Table 2, this increase is more noticeable in regions where tractor density is already high, such as the Aegean, Western and Eastern Marmara, Western Black Sea and Mediterranean. These regions stand out as regions where agricultural machinery and tractor usage are more widespread. On the other hand, it is observed in Table 2 that the differences between Northeastern, Central Eastern and Southeastern Anatolia and other regions are increasing gradually. The rate of increase in the tractor park in these regions may be lower than in the western regions where tractor use is more intensive. This shows that agricultural mechanisation and tractor use differ regionally and some regions seem to be progressing faster in the increase of tractor park.

**Table 2.** Distribution of tractor park according to statistical regional units of Türkiye (TÜİK, 2020)

| Statistical Regions | Number of Tractors (unit) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | % | 2016 | % | 2017 | % | 2018 | % | 2019 | % |
| TR1 İstanbul | 4508 | 0.36 | 4483 | 0.35 | 4504 | 0.34 | 5132 | 0.39 | 5175 | 0.38 |
| TR2 Batı Marmara | 123189 | 9.77 | 125132 | 9.83 | 125759 | 9.62 | 126318 | 9.48 | 126562 | 9.34 |
| TR3 Ege | 259010 | 20.55 | 261512 | 20.53 | 274268 | 20.99 | 279812 | 21.00 | 286735 | 21.16 |
| TR4 Doğu Marmara | 131404 | 10.43 | 133147 | 10.45 | 134194 | 10.27 | 135392 | 10.16 | 136545 | 10.08 |
| TR5 Batı Anadolu | 113412 | 9.00 | 113590 | 8.92 | 116191 | 8.89 | 117312 | 8.81 | 118194 | 8.72 |
| TR6 Akdeniz | 159574 | 12.66 | 161771 | 12.70 | 165765 | 12.69 | 168420 | 12.64 | 171689 | 12.67 |
| TR7 Orta Anadolu | 129153 | 10.25 | 131757 | 10.35 | 134304 | 10.28 | 137218 | 10.30 | 138802 | 10.24 |
| TR8 Batı Karadeniz | 181652 | 14.41 | 181587 | 14.26 | 183673 | 14.06 | 186247 | 13.98 | 188823 | 13.94 |
| TR9 Doğu Karadeniz | 13506 | 1.07 | 14018 | 1.10 | 14899 | 1.14 | 15164 | 1.14 | 15402 | 1.14 |
| TRA Kuzeydoğu Anadolu | 42122 | 3.34 | 42759 | 3.36 | 46884 | 3.59 | 49025 | 3.68 | 51504 | 3.80 |
| TRB Ortadoğu Anadolu | 36634 | 2.91 | 37079 | 2.91 | 37960 | 2.91 | 42758 | 3.21 | 44002 | 3.25 |
| TRC Güneydoğu Anadolu | 66194 | 5.25 | 66696 | 5.24 | 68335 | 5.23 | 69341 | 5.21 | 71479 | 5.28 |
| **TÜRKİYE** | **1260358** | **100** | **1273531** | **100** | **1306736** | **100** | **1332129** | **100** | **1354912** | **100** |

Expanding the use of tractors and supporting agricultural mechanisation can contribute to making agriculture more sustainable and competitive (Korucu et. al.2015). When we analyse the tractor parks in Türkiye by region, the Aegean Region stands out as the region with the largest park with approximately 290,000 tractors. This region is followed by the Western Black Sea and Mediterranean regions with tractor parks ranging from 170,000 to 188,000. Eastern and Western Marmara and Western Anatolia regions have tractor assets ranging between 110,000 and 140,000. Among the other regions, Southeastern and Central Eastern Anatolia regions with less than 100,000 tractors are noteworthy. Although these regions have high agricultural potential, they have lower numbers of tractor parks.

When we look at the size and power groups of tractor parks in Table 2, it is seen that in regions with large parks, low power group tractors are in majority because of agricultural product patterns and enterprise structures of these regions. In high tractor intensed regions, product patterns such as fruit and vegetable farming, which generate higher income compared to field agriculture, are generally intensive. Also, smaller scale enterprises are common in these regions. Therefore, the majority of tractors are low-horse power, as they are sufficient for such enterprises. On the other hand, Istanbul, Western Marmara, Western and Northeastern Anatolia regions have more higher horse power tractors compared to other regions. The high number of high-powered tractors in Istanbul originates from a commercial practice rather than the characteristics of agriculture. High-powered tractors are mostly purchased through financial leasing and since financial leasing companies have their headquarters in Istanbul, their registration records are kept in this province. The high concentration of high-power tractors in the West Marmara, Western and Northeastern Anatolia regions can be explained by the fact that field agriculture is carried out more and there are relatively large-scale enterprises in these regions,. Enterprises may prefer high-powered tractors since they have larger lands. Such data shows that tractor utilisation and power levels may differ depending on the regional agricultural structure and enterprise types. Therefore, it is important that tractor parks are should be diversified and well adapted to the needs.

### 3.4. *Mechanisation level in Türkiye*

As seen in Table 3, Turkish agriculture has made significant progress between 2015-2018 in terms of mechanisation level. During this period, it was found that there were large differences in the level of mechanisation between the statistical regions of Türkiye. Tractor power per unit cultivated area (kW/ha): Among the statistical regions, tractor power values per unit cultivated area vary between 0.38 and 4.56 kW/ha. This shows that agricultural lands differ according to tractor power.

**Number of tractors per 1000 ha cultivated area (Tractor/1000 ha):** This value varies between 20.24 and 129.61 tractors/1000 ha between regions. This shows that the number of tractors per thousand hectares of cultivated area is different according to the regions.

**Cultivated area per tractor (ha/tractor):** The area cultivated per tractor varies between 7.72 and 49.42 ha/tractor among the statistical regions. This shows that the size of the land cultivated by tractors is different according to the regions.

**Table 3.** Mechanization level data for Türkiye and geographical regions (TÜİK, 2019)

| Geographical Regions | Kw/ha | | | | Tractor/1000ha | | | | Ha/Tractor | | | | Equipment/Tractor | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2015 | 2016 | 2017 | 2018 | 2015 | 2016 | 2017 | 2018 | 2015 | 2016 | 2017 |
| Northeastern Anatolia | 1.38 | 1.44 | 1.52 | 164 | 33.16 | 34.45 | 36.27 | 38.74 | 30.16 | 29.03 | 27.57 | 25.81 | 8.34 | 8.32 | 7.89 |
| Middleeast Anatolia | 1.02 | 1.04 | 1.10 | 1.29 | 28.36 | 28.94 | 30.57 | 34.90 | 35.27 | 34.55 | 32.71 | 28.65 | 10.31 | 7.85 | 8.06 |
| Southerneast Anatolia | 0.88 | 0.91 | 0.96 | 0.99 | 22.74 | 23.59 | 24.64 | 25.54 | 43.98 | 42.39 | 40.59 | 39.15 | 7.07 | 7.11 | 7.08 |
| Istanbul | 2.54 | 2.48 | 2.53 | 2.86 | 63.08 | 61.52 | 62.54 | 71.04 | 15.85 | 16.26 | 15.99 | 14.08 | 8.77 | 8.81 | 9.02 |
| West Marmara | 3.21 | 3.17 | 3.23 | 3.26 | 82.68 | 81.78 | 83.16 | 84.06 | 12.09 | 12.23 | 12.03 | 11.90 | 7.97 | 7.95 | 7.96 |
| Egean | 4.08 | 4.19 | 4.45 | 4.56 | 117.56 | 120.46 | 126.84 | 129.61 | 8.51 | 8.30 | 7.88 | 7.72 | 7.42 | 7.42 | 7.23 |
| East Marmara | 3.24 | 3.37 | 3.40 | 3.54 | 95.29 | 98.51 | 98.95 | 102.68 | 10.49 | 10.15 | 10.11 | 9.74 | 6.72 | 6.73 | 6.78 |
| West Anatolia | 1.29 | 1.29 | 1.37 | 1.38 | 32.72 | 32.61 | 34.38 | 34.63 | 30.57 | 30.66 | 29.08 | 28.88 | 7.69 | 7.72 | 7.80 |
| Mediterrenian | 2.64 | 2.68 | 2.80 | 2.89 | 75.84 | 77.02 | 79.90 | 82.32 | 13.19 | 12.98 | 12.52 | 12.15 | 7.98 | 8.16 | 8.20 |
| Central Anatolia | 1.33 | 1.38 | 1.45 | 1.50 | 34.64 | 35.76 | 37.49 | 38.43 | 28.87 | 27.97 | 26.67 | 26.02 | 7.08 | 7.03 | 7.02 |

**Cultivated area per tractor (ha/tractor):** The area cultivated per tractor varies between 7.72 and 49.42 ha/tractor among the statistical regions. This shows that the size of the land cultivated by tractors is different according to the regions.

**Number of equipment per tractor (Equipment/Tractor):** The number of equipment per tractor varies between 4.65 and 14.08 equipment/tractor across regions. This indicates that tractors have different equipment for the tasks they are used for.

**Number of combine harvesters per 1000 ha cultivated area (Combine Harvester/1000 ha):** This value varies between 0.02 and 2.62 harvester/1000 ha among the statistical regions.This shows that the number of harvesters per thousand hectares of cultivated area is different according to the regions.

These statistics show that agricultural mechanisation varies in different regions of Türkiye and these differences have significant effects on agricultural productivity. Therefore, it is necessary to formulate and develop mechanisation strategies according to the agricultural necessities and characteristics of each region (Altuntaş, 2016).

Developments in tractor intensity, when compared with some selected countries, show that Türkiye is ahead of countries such as Egypt, Pakistan and Mexico, but behind European countries (FAOSTAT, 2006). Moreover, when it is taken into consideration that the average power of the tractor parks of European countries is two times higher than that of Türkiye. This result is due to the fact that European countries have a high level of mechanisation in crop production as well as developed animal production and intensive use of tractors in this field. Therefore, when comparing tractor intensity, not only crop production but also animal production and tractor use in this field should be taken into consideration. The fact that the tractor intensity of the USA does not correspond to other data is the result of the high average tractor power in the country, and the enterprise structure and production technologies used also affect this situation.

### 3.5. *Problems of agricultural machinery in parks in Türkiye*

According to 2020 traffic records, there are a total of 1.958.727 tractors in Türkiye. The average age of these tractors is 25,3 years. There are approximately 945,000 tractors aged 25 years and older in the park and the average age of these tractors is 40.3 years. There are approximately 650,000 tractors over 35 years old. In addition, the average age of about 500,000 tractors over 40 years old is 47.8 years. Based on these data, we can say that half of the tractors in the park have completed their economic useful life. However, tractors should be evaluated not only according to their age, but also in terms of the technology and equipment they contain. Especially in tractors over a certain age, basic components such as PTO and hydraulic systems may be missing and there may be no four-wheel drive unit. Working with tractors that have completed their mechanical and economic life can lead to economic losses ( Table 4). One of these losses is excessive fuel and oil consumption. In addition, it has a significant impact on product efficiency and quality in agricultural activities and may cause loss of working time (Toğa, 1994).

Such tractors also carry a high risk of accidents and a high risk to life safety. Moreover, end-of-life tractors can lead to high levels of environmental pollution (such as CO2 emissions). Therefore, the continued use of ageing and technologically outdated tractors can have various negative consequences.

Although many farmers are aware of the economic losses caused by working with end-of-life tractors, they may not have the means to renew or modernise these tractors due to economic difficulties. Furthermore, some farmers use their tractors as a debt instrument to meet their financial needs. This means renewing tractors that have not completed their economic life through trade-in and buying them with long-term debts. However, this practice can push second-hand tractor prices well above their real value. When tractors are reached the end of their economic life they will consume average 700 litres fuel per year excessively and cause 100-150 hours of lost work. In addition, when calculated based on the exhaust emission measurements of tractors over 25 years old, it is estimated that these old tractors generate an average of 1,816 kg of additional $CO_2$ emissions per year (Evcim et.al.2007).

**Table 4.** Cost of a tractor that has completed its economic life (TÜİK, 2019)

| Losts | Annual Cost (TL/Tractor) |
|---|---|
| Fuel | 4550 |
| Maintenance and Repair | 2000 |
| Work Loss | 9000 |
| Carbon Emission | 344,43 |
| Total | 15894,43 |

The cost of losses caused by a tractor that has reached the end of its economic life is calculated as 16 thousand Turkish liras per tractor according to current data. According to 2019 data, there are 1.354.912 tractors in the tractor park in Türkiye and 664.000 of them are older than 25 years old. When calculate the annual economic losses caused by tractors reaches approximately 11 billion Turkish Liras. This shows an extra cost that old tractors impose on operating costs and the national economy annually (Gürsoy, 2012). When analysing combine harvester ages situation in park it is observed that most of the crop losses are in barley and wheat products, followed by maize, rye and oats, respectively. When the total production amounts are considered, it is determined that production losses constitute 5% of the total production amount and correspond to 1.687.150 tonnes of product loss. Especially when considered on a country-wide scale, the monetary equivalent of this crop loss is approximately 382,42 million Turkish Liras. In case of renewal of the combine harvester park, it is planned to gradually reduce this loss and contribute to the national economy.

## 4. Conclusion

In order to solve the problems of Türkiye's tractor and combine harvester park, the rejuvenation of this park should be urgently addressed. A Scrap Rebate program can be considered to support the country's resources rationally and efficiently. This program can be a framework for addressing and resolving long-term problems. For the Scrap Discount application, a commission must be formed to include all relevant stakeholders. This commission should include all relevant parties such as the Ministry of Industry and Technology, the Ministry of Agriculture and Forestry, the Ministry of Treasury and

Finance, the General Directorate of Police, HURDASAN, universities and relevant non-governmental organizations. This commission can generate the general principles regarding the Scrap Discount application. In addition, incentive regulations should be introduced so that those who will purchase a new tractor can benefit from low-interest or interest-free loan opportunities. The attractive scrap discount amount may be an incentive for farmers who want to renew the existing park. (Toga, 1994)

When planning a tractor or combine harvester replacement, the characteristics and requirements of the enterprise should be taken into account. These decisions should be based on the type of crops grown, the number of machines and operations used in agricultural production processes, technical and economic data, land size, future growth prospects and other factors. Additionally, all of these factors should be taken into account when choosing the optimal power range.

During the planning phase, realistic mechanization models should be created according to factors such as the size and geographical location of the enterprise. These models should be considered at different levels, starting from the business level to business groups, basins, regions and the country. It would be a correct approach to take into account especially smaller basins with similar characteristics. Existing machines should be tested and maintained at regular intervals to maintain their usability. This is important to support the long-term use of tractors and combine harvesters and minimize economic losses.

Encouraging domestic production can strengthen the domestic agricultural machinery industry and offer domestic producers the opportunity to increase capacity and create new job opportunities. This could also contribute to the revival of the economy. Local production also has the potential to better adapt to the needs of local agricultural machinery.

It is important to create data infrastructure for tractors and agricultural machinery. A system should be created where producers can record their machinery and tractor inventories and keep this information up-to-date. This allows machines to be rented, shared and managed more effectively. Additionally, digital platforms and applications that can be used for rentals and rapid communication should also be developed.

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## Author Contribution

The authors' contributions to the study should be clearly stated as follows:.
S.A. (initials of the author's name. initials of the author's surname): writing the article, creating the experimental setup, and performing the experiments.
S.A.: Literature research and statistical calculations of the data.
B.P. : interpretation of the findings, literature research, and obtaining the necessary materials for the experiment.

The authors declare that they have contributed to the study on the subjects mentioned above.

**Conflict of Interest Declaration Information (required field)**

There is no conflict of interest.

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