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EVALUATION OF AGRICULTURAL MECHANIZATION AS AN INDICATOR OF AGRICULTURAL DEVELOPMENT: A COMPARATIVE STUDY FOR TÜRKİYE AND EGYPT

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Abstract: Nowadays, one of the main goals of agriculture is to meet the needs of human communities in all countries through more efficient and high-quality production in agricultural areas. The incorporation of technological advancements, particularly agricultural mechanization, has become imperative for enhancing agricultural production. In recent years, the growing need and inclination to minimize reliance on human labor have heightened the significance of agricultural mechanization, its continual development, and its integration into agricultural operations. The progress of agriculture is intricately tied to the adoption of production technologies within the agricultural sector. The heightened integration of new and contemporary technologies in agriculture can elevate agricultural productivity and income while concurrently lowering production costs. The degree of a country's agricultural development is inherently linked to the utilization of production technologies within its agricultural practices. This research aims to study the existing state of agricultural mechanization in Türkiye and Egypt by identifying and measuring important indicators of the mechanization level of farming, focusing on conducting a comparative analysis between the two countries. Türkiye has a total cultivated area of approximately 23 million hectares, whereas Egypt's cultivated area is around 3 million hectares. Tractors equipped with mechanical power supplies, constituting a fundamental energy source in agriculture, in this study are estimated to be approximately 1.354.912 and 135.100 in Türkiye and Egypt, respectively. The results showed that the levels of mechanization in Türkiye and Egypt were represented by engine power per hectare (1.28 kW/hectare and 0.93 kW/hectare), the number of tractors per 1000 hectares (58.91 tractor /1.000 hectare, and 45 tractor /1.000 hectare) and the cultivated area per tractor (16.97 ha/tractor and 22.21 ha/tractor), respectively. Additionally, the average tractor power in Egypt and Türkiye reached 33-41 kW and 44-52 kW, respectively.

Keywords: Agriculture, Mechanization level, Tractors, Agricultural machinery

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1. Introduction

The global population stood at 7.5 billion in 2017, with projections indicating an increase to 8.5 billion by 2030 and 9.7 billion by 2050. In order to provide the population's food needs, the agricultural sector assumes a pivotal role in addressing the nutritional requirements of the populace. It substantially contributes to national income, employment, and foreign trade. Consequently, the imperative to enhance productivity within this sector becomes pronounced (FAO, 2017).

There are two types of technology utilized in the agriculture industry. These are mechanical and biological technology. Biotechnology encompasses several breeding practices, including the production of seeds, fertilizers and pharmaceuticals. It is conceivable to create things that are more robust and healthy than high-productivity items, especially with this technology. Mechanical technology typically encompasses mechanization, incorporating elements such as tractors, tractor-utilized tools and machinery, irrigation equipment, and livestock machinery. The implementation of mechanization in agricultural enterprises results in efficiencies, yielding savings in labor, time and production costs (Tarmakbir, 2018).

Agricultural mechanization constitutes a sector within agricultural machinery, with the overarching goal of enhancing the vitality of agricultural areas, augmenting the diversity of agricultural production and optimizing the utilization of agricultural products. Positioned as a sub-sector within the manufacturing sector, agricultural mechanization is characterized by its involvement in the production, manufacturing, development, marketing, sales and management of a diverse array of mechanical designs (Anonymous, 2023a).

The primary indicators delineating the extent of agricultural mechanization within a country encompass the quantitative and qualitative assessment of the tractor

fleet, its year-by-year development, its correlation with agricultural machinery, as well as the density and power levels in unit farming (Evcim and Ertuğrul, 2017).

Mechanical technologies in agriculture have played a pivotal role in reshaping the global farming landscape. These technologies have not only led to an expansion in farm size but have also perpetuated the ongoing trend of displacing or substituting farm labor (McNulty and Grace, 2009).

Agricultural mechanization entails the substitution of human labor across the value chains of crops, livestock and aquaculture with the utilization of animal or mechanical power (Daum and Kirui, 2021). While agricultural motorization concentrates on the use of mechanical power, which can be powered by fossil or renewable energy (FAO and AUC, 2018).

In developed nations, research indicates that emerging technologies, such as agricultural robotics, will persist in displacing and substituting farm labor (Schmitz and Moss, 2015). Moreover, specific studies indicate that while the need for manual labor diminishes with mechanization, this reduction is observed primarily in specific stages of agricultural production, namely land preparation, transplanting, and harvesting (Chandran, 2017).

Mechanization initiatives have predominantly concentrated on large machinery, particularly four-wheeler tractors, along with associated equipment such as tillers, drill machines, rotavators, harvesters, driers, balers, and more. Recent evaluations of these schemes are beginning to surface in literature, with a notable emphasis on output indicators like the quantity of imported and distributed equipment (Daum and Birner, 2017).

Agricultural mechanization has been characterized in various ways, with the most encompassing and pertinent definition being the one that encompasses all facets of farming and processing technologies. This ranges from elementary hand tools to more advanced, and motorized equipment, as reported by the Food and Agriculture Organization (FAO, 2016). Mechanization serves to alleviate and diminish strenuous labor, address labor shortages, enhance farm labor productivity, improve the efficiency and timeliness of agricultural operations, optimize resource utilization, facilitate market access, and contribute to the mitigation of climate-related hazards (Sims and Kienzle, 2017).

Baudron et al. (2015) stated that the agricultural mechanization process encompasses multiple facets, ranging from the identification of farm operations suitable for mechanization to the adaptation or production of appropriate machinery.

Agriculture plays a pivotal role in both Türkiye and Egypt. Türkiye is a nation with a population of approximately 80 million people, and 81 provinces. The total utilized agricultural land in the country is approximately 38,3 million hectares, with 15,6 million hectares dedicated to cereals and other crops (TÜİK, 2017a). Noteworthy production areas for crops harvested by combine harvesters include 7,7 million hectares for wheat, 2,4 million hectares for barley, 0,8 million hectares for sunflower, 0,6 million hectares for corn, and 0,03 million hectares for soybeans (TÜİK, 2017b), while Egypt, with a total land area of approximately one million km^2. The country boasts a cultivated area of 3,6 million hectares, with around 2,7 million hectares concentrated in the Delta Region, benefiting from surface irrigation. Additionally, 0,88 million hectares consist of newly reclaimed soils, utilizing pressurized irrigation methods such as sprinkler and pivot irrigation (Peter and Sewilam, 2016).

The agricultural sector in Türkiye is a significant economic and social domain, exerting influence on nutrition, employment, national income, and the provision of raw materials to the industrial sector (Sümer et al., 2004; Anonymous, 2023b). The Egyptian economy is presently undergoing a process of liberalization and privatization, with a pronounced impact on the agricultural sector, which constitutes a pivotal aspect of the nation's economic framework. Egypt's economy has been heavily dependent on the agricultural sector. Approximately 55% of the population derives their livelihood from agriculture, which serves as a source of employment for about 34% of the total labor force. Furthermore, agriculture contributes around 20% to the gross domestic product (GDP), approximately 20%, of total exports and foreign exchange earnings (Kadah et al., 2018; World Bank, 2019).

Despite Türkiye surpassing the global average in terms of the criteria defining current agricultural mechanization, there remains an imperative to elevate both the existing production levels and productivity. This is particularly crucial to meet the increasing demand for agricultural production. Achieving a higher degree of effectiveness in planning the agricultural mechanization levels across regions in Türkiye involves diversifying the tractor and agricultural machinery fleet, as suggested by Altuntas and Demirtola (2004).

Soil cultivation equipment and machinery are extensively utilized in Türkiye. Additionally, the projection coefficients, along with other pertinent information, were determined for machines involved in sowing, planting, fertilizing, harvesting, and spraying, as well as tractor and trailer units equipped for silage, mowing, and baling operations (Baran et al., 2019).

The aim of this study was to determine the level of agricultural mechanization in Türkiye and Egypt considering the existing status of agricultural potentials in both countries.

2. Materials and Methods

The material of this study consists of the number of agricultural tractors according to powers, the data obtained from the Turkish Statistical Institute (2023) for Türkiye and the Ministry of Agriculture and Land Reclamation (2019) for Egypt. Additionally, the data on

surface area and cultivated area for both countries has been obtained from the Food and Agriculture Organization of the United Nations Statistics (2023).

Mechanization level signifies the proportion of total tensional powers relative to the under-cultivated area. This index provides insights into the extent to which mechanical forces are applied to the cultivated land, offering a valuable indicator of the overall mechanization intensity in a given area.

The criteria for determining the level of mechanization for Türkiye and Egypt as shown in the following indicators:

A. The average of tractor powers (kW).

B. The number of tractors per 1000 hectares (tractor/ 1.000 hectare).

C. The cultivated area per tractor (ha /tractor).

D. Mechanization level (Power availability).

According to Pishbin (2013), the level of mechanization is determined as shown in the following equations 1, 2 and 3;

$$ML = \frac{Pm \times Cf}{A} = \frac{\text{Total real power}}{\text{cultivated area}} \quad (1)$$

Where:

ML = mechanization level (kW/ha).

pm = Total power of tractors (kW).

Cf = Convey coefficient (0,5 or 0,75 for waste and useful instruments respectively).

A = Total cultivated area (ha).

The total power of existing tractors (kW) = Average nominal of one tractor × Number of working tractors (2)

The total real power of tractors = Total power of existing tractors × conversion coefficient (0.75) (3)

Egypt takes a broad view of food security, recognizing that with limited arable land and water resources, it will never be self-sufficient in grains, vegetable oil, and animal proteins 40% of Egypt's imports are food and agricultural products. The agricultural vision for Türkiye in 2023 delineates ambitious objectives, with the primary goal being the transformation of Türkiye into a nation capable of supplying its population with ample, high-quality, and safe food. Additionally, the vision aims to enhance Türkiye's position as a net exporter of agricultural products, strengthen its competitive edge, and establish leadership in the field of agriculture both within its regional context and globally.

Table 1 presents a comparative analysis of the land area in Türkiye and Egypt for the year 2021; encompassing both total agricultural lands and the specific area designated as arable land with 1.000 hectares (FAO, 2023).

Table 1. Comparison between Türkiye and Egypt in terms of agricultural land area in 2021

Items	Area (1000 ha)	
	Türkiye	Egypt
Country area	78.535	100.145
Agricultural land	38.089	4.031
Cultivated area	23.000	3.000
Cropland	23.473	4.031
Arable land	19.881	3.077
Permanent crops	3.591	954

In Türkiye, there exist 13 manufacturers specializing in tractors and over 1.000 enterprises engaged in the production of agricultural machinery. The progressive rise in the exportation of tractors, agricultural equipment, and machinery from Türkiye is playing a significant role in bolstering the country's economy (Akdemir, 2013). In Egypt, there are approximately 9 companies that assemble and manufacture some agricultural equipment and machinery (MALR, 2019).

3. Results and Discussion

Agricultural mechanization plays a strategic role in improving agricultural production and productivity in developing countries. Tractor is the main important indicator taken into consideration in the activities of agricultural areas for determining the mechanization level in all countries.

Initially, upon looking at the number of tractors in both Türkiye and Egypt, it is observed that since the 1980s, Türkiye's tractor market has experienced rapid growth alongside advancements in agricultural production. The total number of tractors has surged by more than 3,5 times. As a developing country, statistical reports from 2022 indicate that there are 1.526.769 registered tractors in Türkiye, according to the Ministry of Agriculture and Forestry (Anonymous, 2023c) as shown in (Figure 1).

In contrast, Figure 2 shows the total number of tractors for agricultural purposes, including private, public sector, and government sectors in Egypt during the period from 2011 to 2019 as reported by CAPMAS (2020).

Table 2 presents the number of tractors in Türkiye for the years 2014 and 2022, categorized by power groups (Anonymous, 2023c). The data reveals an increase in the total number of tractors from 1.243.300 in 2014 to 1.526.769 in 2022, indicating a growth trend over the

specified period. Similarly, Table 3 outlines the number of tractors in Egypt from 2014 to 2018, categorized by their power (MALR, 2019). The total count stood at approximately 127.704 in 2014 and increased to 136.144 in 2018. This information provides insights into the tractor distribution and changes in Egypt over the specified years.

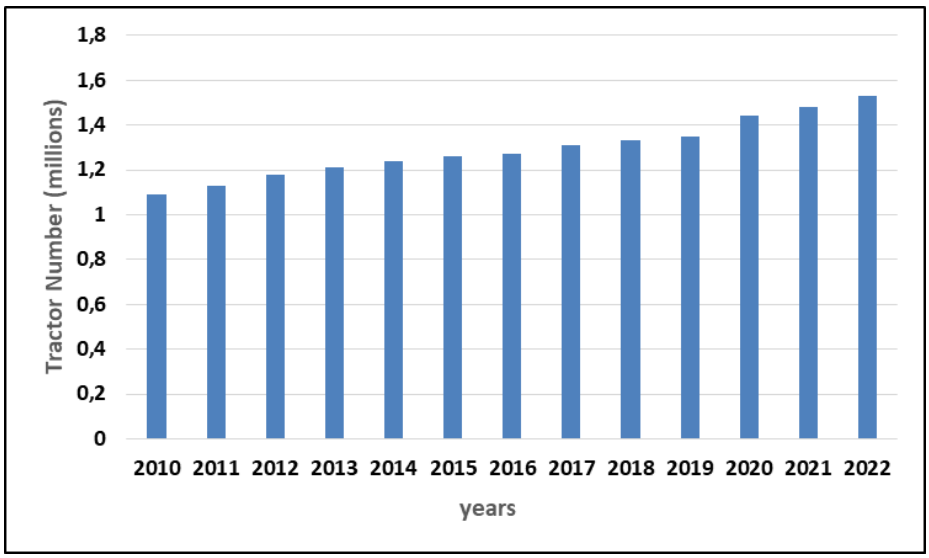

Figure 1. Tractor number changes by year, Türkiye.

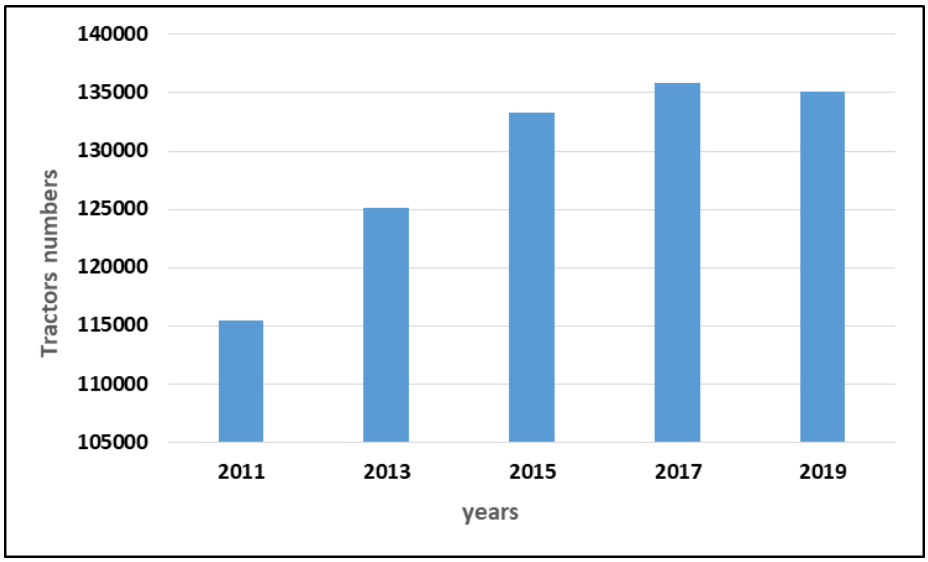

Figure 2. The development of the number of tractors in the agricultural activity, Egypt.

Table 2. Numbers of agricultural tractors according to powers, Türkiye (2014-2022).

Year	Total	One axle		Two axle								
		kW										
		0.75-3.7	4.5-6.7	0.75-7.5	8.25-18	18.75-25.5	26.5-37.5	Change* (%)	38.5-52.5	Change* (%)	52.5 +	Change* (%)
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	0.42	468.060	1.42	135.297	7.78
2016	1.273.531	15.736	57.131	6.448	21.274	66.825	489.621	0.45	475.665	1.62	140.699	3.99
2017	1.306.736	16.589	59.061	6.432	20.527	65.866	492.343	0.55	493.660	3.64	152.133	8.13
2018	1.332.139	17.129	60.707	6.554	20.886	66.104	493.134	0.16	505.087	2.26	162.425	6.77
2019	1.354.912	17.512	62.178	6.589	20.513	65.496	495.375	0.45	513.035	1.55	174.105	7.19
2020	1.442.909	19.416	73.782	6.969	20.944	68.157	517.899	4.50	544.909	6.21	190.677	9.52
2021	1.481.461	20.517	79.658	6.853	20.841	68.730	523.718	1.11	555.536	1.91	205.488	7.77
2022	1.526.769	20.008	84.568	6.384	20.212	68.045	532.393	1.63	570.629	2.64	224.408	9.21
Change* (%)	22.79	39.10	64.23	2.19	-3.32	-1.70	7.79	--	23.67	--	78.75	--

Table 3. Numbers of agricultural tractors according to power categories, Egypt (2014-2018)

Year	Total	kW						
		0,75-26,25	26,25-37,5	Change* (%)	38,25-52,5	Change* (%)	52,5 +	Change* (%)
2014	127.704	10.358	14.817	--	74.635	--	27.894	--
2015	133.298	12.421	16.600	10,74	74.339	0,39	29.938	6,83
2016	135.090	11.095	18.018	7,86	74.765	0,57	31.212	4,08
2017	136.683	9.385	19.682	8,45	72.775	2,73	34.841	10,41
2018	136.144	9.236	20.080	1,98	73.278	0,69	33.550	3,85
Change* (%)	6,61	-10,83	35,52	-	-1,82	-	20,28	-

In Türkiye, the examination of single-axle tractors within the 0.75-3.7 kW range reveals a consistent increase from 2014 to 2022. Furthermore, there is a continuous upward trend in single-axle tractors with more than 3.7 kW. The quantity of double-axle tractors in the 0.75-7.5 kW range remains notably low. Notably, the number of tractors in the 26.5-37.5 kW range has risen from 493.914 in 2014 to 532.393 in 2022. Similarly, the tractor group within the 38.5-52.5 kW range has experienced continuous growth. Particularly noteworthy is the recent increase in tractors with a power exceeding 52.5 kW in the later years of the observed period.

When comparing the number of single-axle tractors in Türkiye between 2014 and 2022, there was a notable 39.10% surge in the 0.75-3.7 kW category and a substantial 64.23% increase in tractors with over 3.7 kW. As for double-axle tractors, there was a modest 2.19% rise in the 0.75-7.5 kW category, a 3.32% decline in the 8.25-18 kW category, and a 1.7% reduction in the 18.75-25.5 kW category. On the contrary, there was a growth rate of 23.67% in the 38.5-52.5 kW categories and a substantial increase of 78.75% in the category exceeding 52.5 kW.

In Egypt, the analysis of tractors within the 0.75-26.25 kW range indicates a decline from 2014 to 2018. However, there is a notable increase in tractors falling within the 26.25-37.5 kW range. In contrast, the quantity of tractors within the 38.25-52.5 kW range has decreased, dropping from 74.635 in 2014 to 73.278 in 2018. Additionally, there is a conspicuous rise in the number of tractors with a power exceeding 52.5 kW during the specified period.

Analyzing the tractor data in Egypt from 2014 to 2018 indicates a decline of 10.83% in the 0.75-26.25 kW category, juxtaposed with a notable increase of 35.52% in tractors within the 26.25-37.5 kW power range. Additionally, there was a modest 1.82% decrease in the 38.25-52.5 kW category, while the category of tractors with more than 52.5 kW experienced a straightforward growth rate of approximately 20.28%.

To effectively compare the mechanization status between Türkiye and Egypt, it is imperative to have a comprehensive understanding of the mechanization indicators in each nation.

By using the above indicators to determine the level of mechanization for Türkiye and Egypt. It was found that Türkiye's agricultural mechanization indicators were 58.91 tractor/1.000 hectare, 16.97 ha/tractor, and the level of mechanization was 1.28 kW/hectare. At the same time, Çiçek and Sümer (2017) reported that the average power per unit area in Türkiye was 1.97 kW/ha, based on data from 2014. Subsequently, Saygili and Çakmak (2021) utilized data from 2020 and asserted that the mechanization level in Türkiye had reached 1.69 kW/ha. In addition, Koçtürk and Avcıoğlu (2007) found, in their study, that the level of agricultural mechanization across various regions in Türkiye was 1.75 kW/ha.

In this context, Egypt's agricultural mechanization indicators were 45 tractor/1.000 hectare, 22.21 ha/tractor, and the level of mechanization was 0,93 kW/hectare, respectively. The average tractor power was 44-52 kW and 33-41 kW, respectively.

When assessing the recent advancements in level mechanization, it becomes evident that Türkiye has experienced a more pronounced increase compared to Egypt as shown in (Figures 3, 4, and 5).

Although the surface area of Egypt is larger than the surface area of Türkiye,. Türkiye has a larger cultivated area. This indicates that the number of tractors used in Türkiye is higher than the number of tractors used in Egyptian agricultural lands as shown in (Figure 6).

Türkiye is home to a fleet of more than 17 thousand combine harvesters, actively engaged in harvesting cereal, corn, soybean, and sunflower crops across a vast expanse exceeding 10 million hectares, in Egypt, a substantial number of combine harvesters have been employed for comprehensive wheat harvesting and threshing. Upon analyzing the evolution in the quantity of combine harvesters over the past decade in Türkiye, there has been a notable 28% increase. Given that cereals constitute the primary agricultural products and serve as raw materials for various industries, these transformations carry significant implications, particularly in reducing dependence on imports. As a prevalent usage model, the adoption of shared combined usage among entrepreneurs is becoming more widespread. Nevertheless, the degree of mechanization in harvesting processes in Egypt has not attained a significant level as shown in (Figure 7) with the comparison with Türkiye.

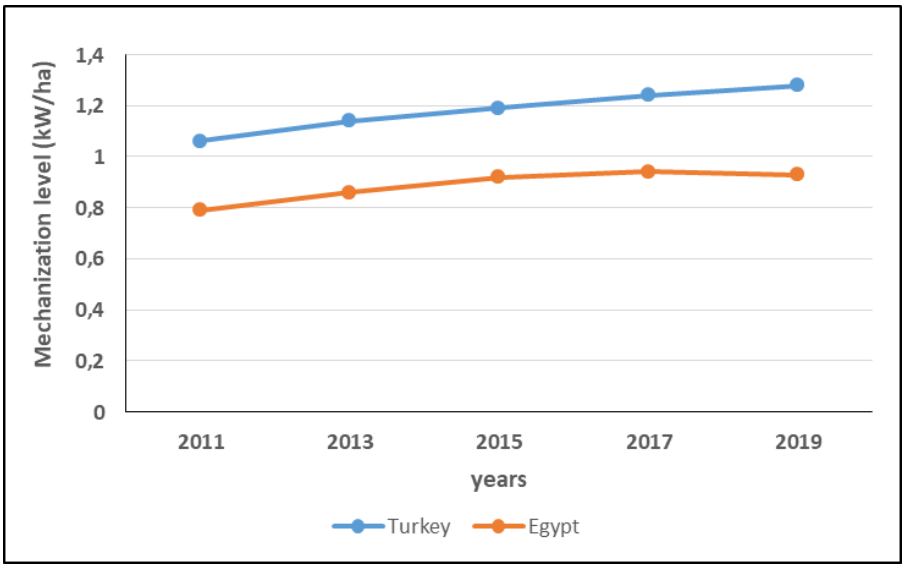

Figure 3. Mechanization level in Türkiye and Egypt.

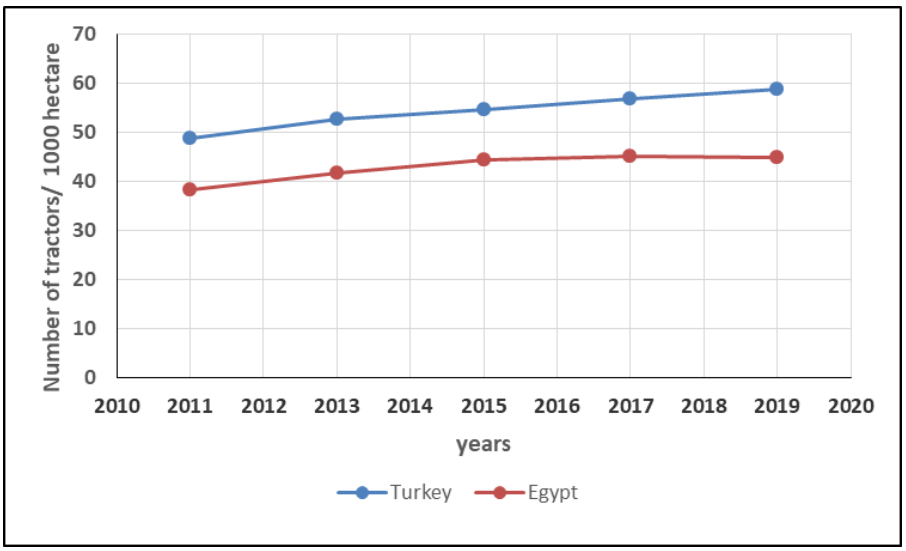

Figure 4. Comparison between the number of tractors per 1000 hectare for Türkiye and Egypt.

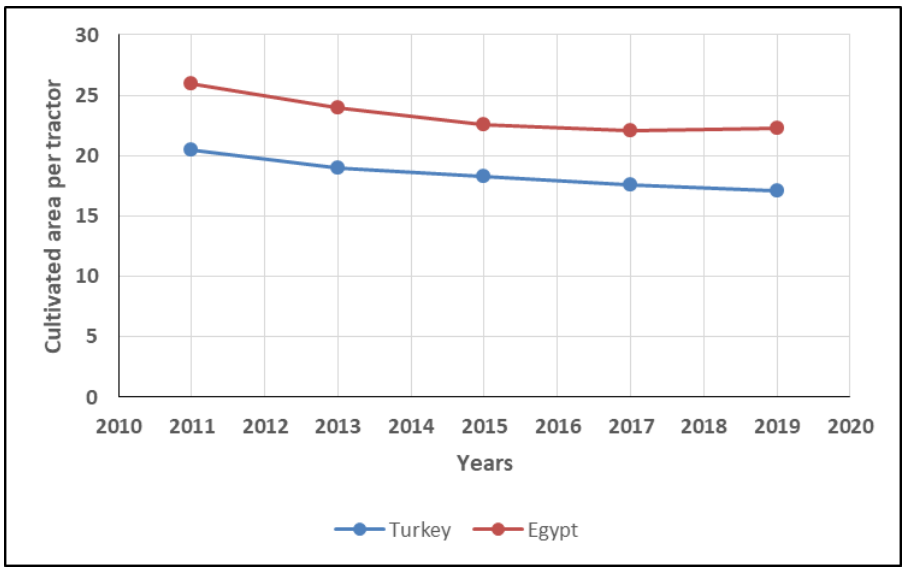

Figure 5. Comparison between the cultivated area per tractor for Türkiye and Egypt

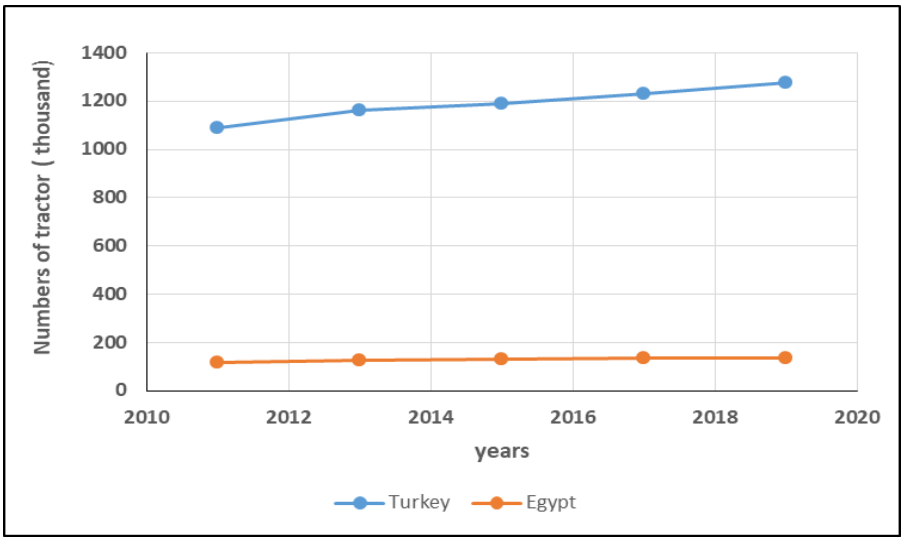

Figure 6. The number of tractors in Türkiye and Egypt.

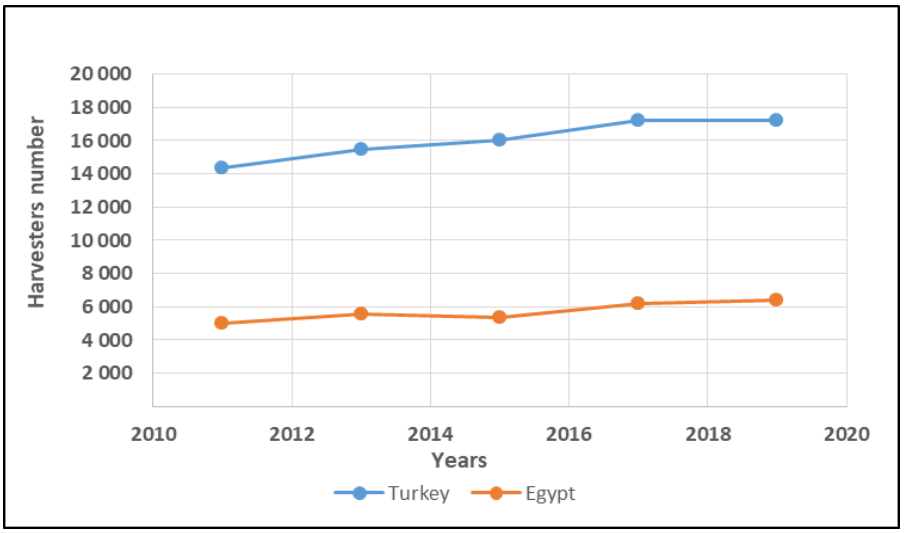

Figure 7. The comparison of harvester numbers between Türkiye and Egypt.

Table 4 outlines Türkiye's agricultural machinery and equipment exports from 2014 to 2021, along with their proportional contribution to the total exports. The data indicates a consistent upward trend in these exports over the ten years. Despite a notable 8.69% decline in 2020, following their global emergence in December 2019, there was a more moderate decrease of 2.66% in 2021. The percentage share of agricultural machinery and equipment in Türkiye's exports, initially at 0.47% in 2010, rose to 0.75% in 2020, and then slightly decreased to 0.73% in 2021 (Trade Map, 2023).

Table 4. Exports of agricultural machinery and equipment in Türkiye (2010-2021)

Year	Total Export (1000 USD)	Total Agricultural Machinery and Equipment Exports (1000 USD)	Rate %
2014	166.504.862	1.022.732	0,61
2015	143.844.066	945.804	0,66
2016	142.606.247	860.669	0,60
2017	156.992.940	951.580	0,61
2018	167.923.862	1.127.056	0,67
2019	180.870.841	1.243.226	0,69
2020	169.657.940	1.264.995	0.75
2021	225.264.314	1.646.014	0,73

Table 5 illustrates the production and export figures for tractors in Türkiye over the years 2014 to 2022 (Tarmakbir, 2022). According to the data, tractor production has seen a noticeable increase, from 66.922 units in 2014 to 82.500 units in 2022. These findings indicate that Türkiye's exportation of tractors makes a substantial and impactful contribution to the overall economic indicators. When analyzing Egypt's tractors and agricultural machinery exports, it is apparent that these products are not locally manufactured for export but are instead acquired through imports from foreign countries. It was found that the number of machines and equipment used in the field of agriculture in Türkiye has increased in recent years compared to Egypt.

Table 5. Number of tractor production, exports, and their corresponding values in thousands of USD in Türkiye (2014 - 2022)

Years	Tractor Production (Units)	Tractor Exports (Units)	Value (1000 USD)
2014	66.922	17.739	434.241
2015	69.978	17.471	374.472
2016	71.955	15.766	338.701
2017	76.071	14.544	320.937
2018	52.357	19.282	423.603
2019	34.393	23.401	481.298
2020	58.710	21.762	417.211
2021	89.000	23.135	524.757
2022	82.500	26.492	584.664
Change* (%)	23,28	49,34	---

*Calculated values

4. Conclusions

The indicators of agricultural mechanization were determined for Türkiye and Egypt to evaluate the status of agricultural mechanization in both countries.

In Türkiye, there has been a notable increase in the percentage of tractors with power exceeding 26.5 kW, rising from 7.79% to 23.67%. Conversely, in Egypt, tractors with the same power have experienced a decline from 35.52% to 1.82%. Additionally, it is important to clarify that the rate of increase in the number of tractors with a power of more than 52.5 kW was on the rise in Türkiye when compared to Egypt.

Türkiye is undergoing a significant transformation in both the production and export of agricultural tractors. The rate of change in tractor production from 2014 to 2022 amounted to approximately 24%. Furthermore, there was a substantial increase in the export of tractors to other countries, with the rate of change reaching approximately 50% over these years. The data reflects a dynamic shift in Türkiye's agricultural machinery sector, indicating noteworthy developments in both domestic production and international trade compared to Egypt.

In this study, it was found that the level of mechanization in Türkiye is much higher than in Egypt. The number of tractors used in Türkiye is greater than the tractors used in Egypt.

The average power of the tractor, the number of tractors per 1.000 hectares, and the cultivated area per tractor in both countries were (44-52 kW and 33-41 kW), (58.91 tractors /1.000 ha and 45 tractors/1.000 ha), (16.97 ha/tractor and 22.21 ha/tractor) in Türkiye and Egypt, respectively. It was found that Türkiye has made significant advancements in the field of agricultural mechanization compared to Egypt.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	H.D.	N.G	G.A.K.G.
C	60	20	20
D	60	20	20
S	70	10	20
DCP	50	30	20
DAI	60	20	20
L	50	30	20
W	60	20	20
CR	60	10	30
SR	60	20	20
PM	50	20	30
FA	40	30	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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