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DETERMINATION OF AGRICULTURAL MECHANIZATION LEVEL OF KIRŞEHIR PROVINCE USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

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Abstract

The aim of this study is to create a spatial database of basic values related to the level of agricultural mechanization with analyzable correlations. This will be helpful for decision-makers for producing policies to be followed in developing the agricultural structure of Kırşehir region.

The agricultural mechanization status in Kırşehir was investigated thorough evaluation of determination criteria of agricultural mechanization level; mean tractor power, mean tractor power per area worked, mean area worked per tractor, mean number of tractors per 1000 ha, mean number of agricultural tools/machines per tractor, mean number of combine harvesters per 1000 ha and mean area per combine harvester. According to 10-year data encompassing 2006–2015:

- Mean tractor power of Kırşehir was 40.82 kW (lowest 27.47 kW in Akpınar, highest 52.38 kW in Kaman county);
- Mean tractor power per area worked was 0.84 kWha^{-1} (lowest 0.63 kWha^{-1} in Çiçekdağı, highest 1.03 kWha^{-1} in Mucur county);
- Mean area worked per tractor 53.16 ha/tractor (lowest 29.88 ha/tractor in Akpınar, highest 79.32 ha/tractor in Kaman county);
- Mean number of tractors per 1000 ha is 22 (lowest 13 in Kaman, highest 34 in Akpınar county);

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- Mean agricultural tools/machines per tractor is 6 (lowest 5 in Akpınar, highest 9 in Çiçekdağı county);
- Mean number of combine harvesters per 1000 ha is 2 (lowest 1 combine harvester per 2500 ha in Kaman, highest 3/1000 ha in Akpınar county);
- Area worked per combine harvester is 895.3 ha (lowest 313.69 ha in Akpınar and highest 2564.5 ha in Kaman county).

Agricultural mechanization level in this region with dominant rural sector was behind the level in the country. This effective database which can be updated and enriched with different aspects forms a basic model for planning-based applications and provides high-detail case monitoring. The database will positively contribute to consistency in decisions to be taken related to agricultural development of the region.

Key words: agricultural mechanization, spatial evaluation, Kırşehir, farming systems

1. Introduction. Agricultural mechanization has become a basic requirement for sustainable agricultural production to reach advanced levels both qualitatively and quantitatively [1]. In this world where agricultural mechanization develops rapidly, it is important that necessary identifications be made, and correct steps be taken in decision-making and application stages during the development process for producers in Turkey to adapt to this rapid change.

Though Turkey is an important agricultural country, its high agricultural potential has not been fully realized. One of the necessary conditions to use sufficient agricultural potential is a high level of mechanization. Though the mechanization level in Turkey is good, it does not appear to have reached the desired levels compared to developed countries. More than half of the 1 300 000 tractors in Turkey are older tractors with economic life completed [2]. Working with tractors which have completed their economic life causes large increases in maintenance-repair costs in addition to fuel and age costs. Additionally, this causes labour and time losses with great importance for product yield and quality in agricultural activities and at the same time increases the risk of accidents [3]. In this context, improvements in agricultural mechanization levels related to the use of tractors in agriculture will ensure qualitative and quantitative increases in agricultural production. The most important criterion noted in determining the agricultural mechanization level in a country is the sole power source of agricultural tractors; however, within the agricultural production chain, the use of tractors should not be considered alone. Agricultural tools and machines used during agricultural production processes, size of agricultural area, tractor power and load on tractors should be considered.

It is very important to investigate the technical properties of agricultural tractors and to know their appropriateness to their aims. In this project, the properties of tractors used in operations were assessed along with agricultural tools and machines. Data were entered into a database in layers according to GIS

rules. Tractor and other agricultural mechanization information for counties were synthesized at the level of county boundaries and entered in the database in layers according to Geographical Information System rules.

There are studies on determining and/or mapping agricultural mechanization level [4–6]. This study goes beyond the determining and mapping process and provides a spatial database which can be periodically updated based not only on statistical resources but also surveys. Consequently, a more reliable database that includes high variety of data is created to enable precise, spatio-temporal evaluation, modelling and traceability abilities for decision makers. Thereof, the database was created by obtaining basic values related to tractor use and agricultural tools-machines in the Kırşehir region and in light of this database, tractor power groups, operation numbers – structure and tools – machine presence were determined. Assessments revealed criteria belonging to present agricultural mechanization levels with the aim of providing qualified scientific support to decision-makers for production of policies to be followed to develop the agricultural structure and farming systems of the region.

2. Material and method. The research was conducted in Kırşehir that is located in Central Anatolia, Turkey. The coordinates for Kırşehir are $39°8'44.99''$N and $34°9'50''$E, respectively. The was research completed in four different stages. These stages were:

- Preparing surveys to be used to determine basic values related to plant production and use of tractors and main correlations, to obtain data about what model and power of tractor are used on a farm basis, when the tractor was bought, odometer (working hour counter) and other values related to the tractors [4, 5].

- Field studies: Applying the surveys in the field and marking on base maps in the laboratory.

- Assessment of data obtained from surveys and review of 10-year data from the Turkish Statistical Institute (Turkstat) 2006–2015 and all data related to mechanization and entry of all data into the geographical information system database in separate layers based on county boundaries [7].

- Correlation and interrogation of data and interpretation to create new data, production of reports and maps.

Criteria of the agricultural mechanization level are calculated for each county and Kırşehir region based on ten years data as follows:

(1) mean tractor power $\mathrm{mtp} = \dfrac{1}{n}\sum_{i=1}^{n}\dfrac{\mathrm{ttp}_i}{\mathrm{tnt}_i}$,

(2) mean tractor power per area worked $\text{mtpa} = \dfrac{1}{n}\sum_{i=1}^{n}\dfrac{\text{ttp}_i}{\text{ta}_i}$,

(3) mean area worked per tractor $\text{mat} = \dfrac{1}{n}\sum_{i=1}^{n}\dfrac{\text{ta}_i}{\text{tnt}_i}$,

(4) mean number of tractors per 1000 ha $\text{mntt} = \dfrac{1}{n}\sum_{i=1}^{n}\dfrac{\text{tnt}_i \cdot 1000}{\text{ta}_i}$,

(5) mean number of agricultural tools/machines per tractor

$$\text{mmt} = \frac{1}{n}\sum_{i=1}^{n}\frac{\text{tnm}_i}{\text{tnt}_i},$$

(6) mean number of combine harvesters per 1000 ha

$$\text{mcht} = \frac{1}{n}\sum_{i=1}^{n}\frac{\text{tnch}_i \cdot 1000}{\text{ta}_i},$$

(7) mean area per combine harvester $\text{mach} = \dfrac{1}{n}\sum_{i=1}^{n}\dfrac{\text{ta}_i}{\text{tnch}_i}$,

where ttp is the total tractor power (kW), tnm is the total number of tools/machines, tnt is the total number of tractors, tnch is the total number of combine harvesters, ta is the total area worked (ha), and $n = 10$ is the number of years.

Surveys to be used in the Merkez, Akçakent, Akpınar, Boztepe, Çiçekdağı, Kaman and Mucur counties in Kırşehir province had sample volumes calculated 74, 24, 36, 38, 56, 81 and 68, respectively, total 377 in order to represent the population in the study. The sample volume was determined with the sampling method using 95% confidence interval and 5% error [8]. Sample size is calculated by

$$n = \frac{Np(1-p)}{(N-1)\sigma^2 + p(1-p)}, \tag{8}$$

where $n = 377$ is the sample size, N is the total number of farmers, $p = 0.5$ is the probability, and σ^2 is the variance.

In the survey study, the following information was identified and reviewed:

- The model and power group of the tractors [9];
- What it is used for and which agricultural tools-machines it is used with [2];
- Product patterns in areas where tractors are used.

For determination of agricultural mechanization level, machines used in agricultural production, agricultural work performed, power sources, and application methods were noted. It is very important to compare agricultural mechanization level with the condition of associating with productivity for operations competing in similar production areas on the axis of accepted criteria [6]. Based on current Turkstat data, the agricultural mechanization levels in Kırşehir province were calculated and mapped as mean tractor power, mean tractor power per area worked, mean area per tractor, mean number of tractors per 1000 ha, mean number of agriculture tools-machines per tractors, mean combine harvesters per 1000 ha and mean area worked per combine harvester [10,11].

With the aim of interrogating the connections between data, GeoMedia Pro 6.1 GIS software was used to determine the geographic distribution and correlations of the data (Fig. 2 and 3).

3. Results. According to results obtained from surveys of farmers, it appears that different brands of tractors are chosen in Kırşehir province. The mean age in the tractor park in Kırşehir (19 years) is lower than the mean age for tractors in Turkey (24 years), apart from Akpınar (25 years) and Çiçekdağı (24 years).

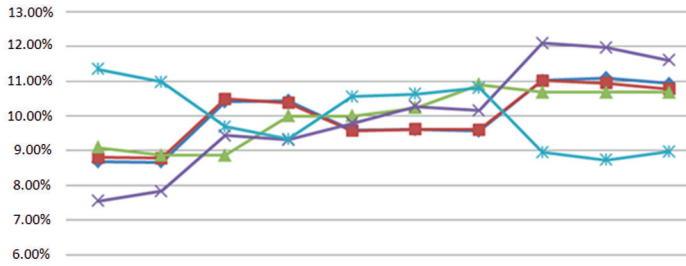
To provide an idea about the economic life of tractors used in Kırşehir province, it is necessary to know the odometer (use duration) values. In international standards, the economic life of a tractor is about 10–12 thousand hours. In Turkey it is expected that the annual use duration is 1000 h, but unfortunately this duration varies from mean 500 to 550 h [12] and it slightly increased from 493.81 (2010) [2] to 511 in Kırşehir. Noting the annual use duration, we can say the maximum life of tractors in our country is 24–25 years. Additionally, nearly half of tractors are over 25 years of age. The mean age of tractors above 25 years is known to be 38.7 years [2,13]. In this context, the tractors used in Kırşehir province are well below this mean and it can be said to be a young tractor park.

The variation in agricultural mechanization level through the years was investigated on a county basis and criteria for Kırşehir province according to years is given in Fig. 1. The mechanization criteria are investigated in the following order:

- The number of combine harvesters per 1000 ha area has risen in recent years, while mean area worked per tractor (ha/tractor) appears to have been reduced.

- The variation in mean number of tractors per 1000 ha area and mean tractor power per area worked (kW/ha) over the years is in proportion and this change appears to have increased in recent years. Both criteria are inversely proportional to area worked per tractor.

- The mean agricultural tools-machine numbers per tractor does not appear to have changed in recent years.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean	CV %	S	S^2
kW/ha	5.04	5.03	6.04	6.06	5.57	5.58	5.55	6.4	6.44	6.35	5.81	9.13	0.53	0.28
Tractor/1000 ha	135	135	161	160	147	148	148	169	168	166	154	8.38	12.88	165.79
Equipment/tractor	40	39	39	44	44	45	48	47	47	47	44	7.95	3.50	12.22
Combine harvesters/1000 ha	10	11	13	13	13	14	14	17	16	16	14	16.16	2.21	4.90
ha/tractor	422.42	408.69	360.47	347.29	392.71	395.58	402.38	333.15	324.71	333.98	372.14	9.70	36.10	1303.41

Fig. 1. Criteria of agricultural mechanization level in Kırşehir province

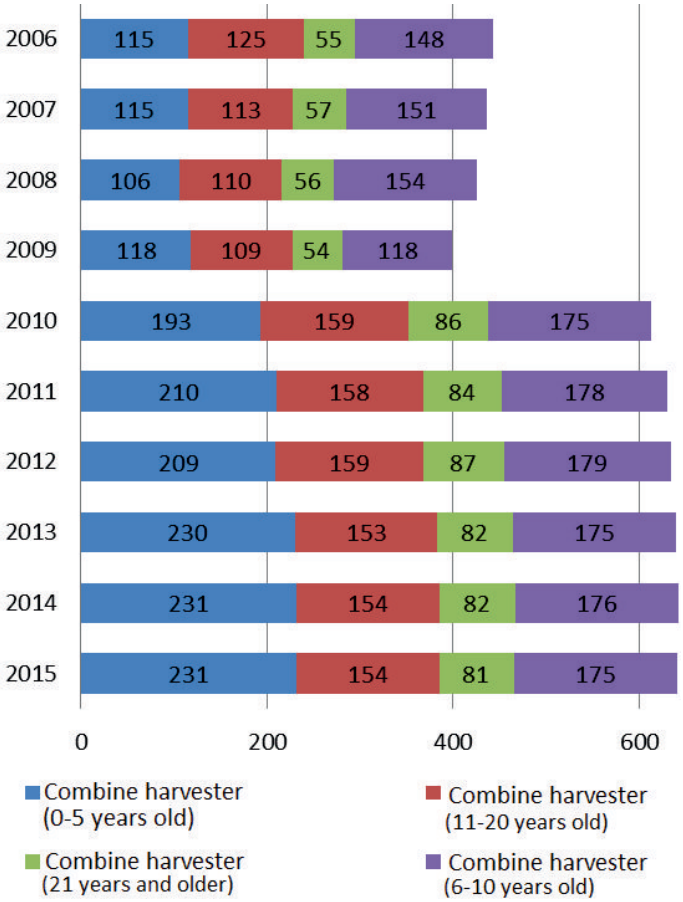


Fig. 2. Distribution of combine harvesters in Kırşehir province according to year

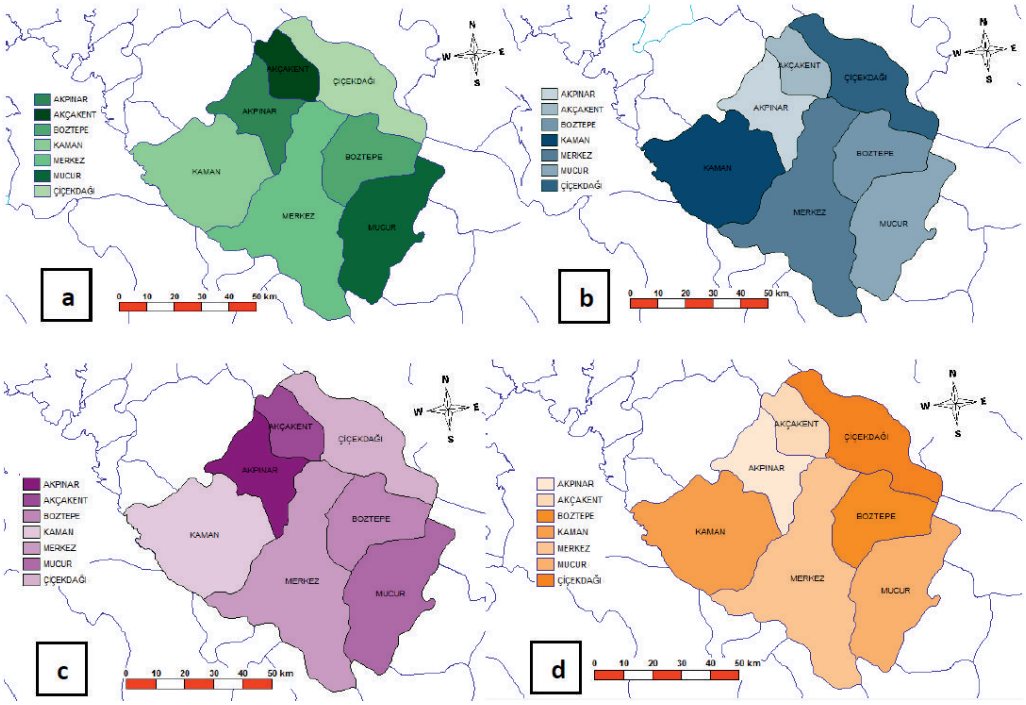


Fig. 3. Mapping of mean agricultural mechanization criteria for year on county basis: a) tractor power per hectare (kW/ha), b) area worked per tractor (ha/tractor), c) number of tractors per 1000 ha (tractor/1000 ha), d) number of equipment per tractor (equipment/tractor)

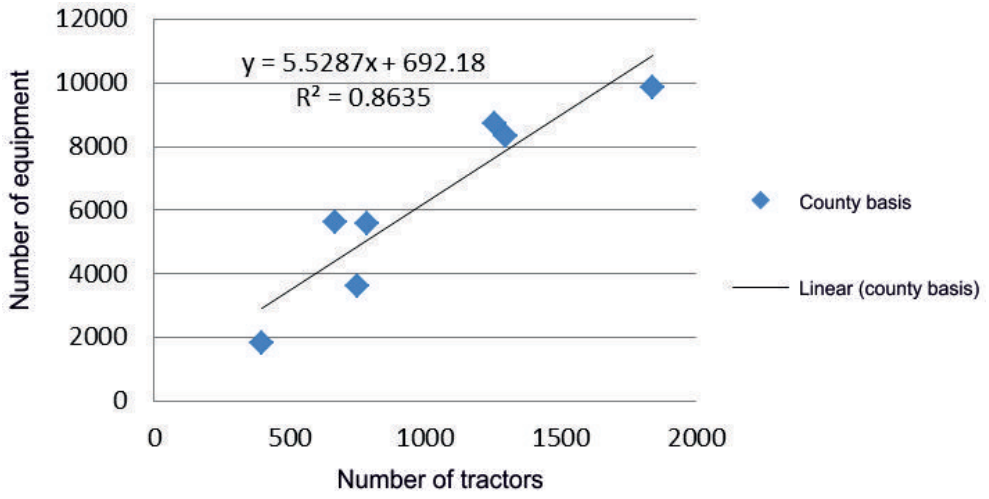


Fig. 4. Correlation of number of tractors with numbers of equipment

The total plant production area in Kırşehir province appears to have reduced rapidly from 2006 to 2009. With agricultural policies and supports applied, the area operated increased in later years, but still has not reached the area operated in 2006. It is thought that increased urbanization and migration is effective.

The counties with highest tractor power were observed to be Kaman, Çiçekdağı, Mucur and Boztepe in that order.

Another criterion used to measure agricultural mechanization level is the size of the area per tractor. Considering the interval from 2006 to 2015 in Kırşehir counties, when the variation in calculated area per tractor is investigated it increased in nearly all counties in 2010, but this was observed to reduce in later years.

Another criterion used to measure agricultural mechanization level is the tractor power per unit area. When the variation in calculated tractor power per unit area in counties in Kırşehir is considered from 2006 to 2015, it reduced from 2006 to 2010 and appeared to rise after 2010.

The variation in combine harvester numbers in Kırşehir province is given in Fig. 2.

The illustration of agricultural mechanization criteria with GIS software is given in Fig. 3. The colour densities on the maps vary according to values in the dataset, darkening as the values increase.

The correlation of the time-linked variation between tractors and equipment numbers is considered present but weak, by noting the consistency coefficient of 0.67. However, when the correlation between tractors and equipment numbers is spatially investigated taking the 10-year means for tractor and equipment numbers in counties in Kırşehir (Fig. 4), as the number of tractors increased, there was a linear increase observed in the equipment numbers on a county basis, with consistency coefficient calculated as 0.86.

4. Discussion and conclusion. Knowing the agricultural mechanization levels of a country with large agricultural sector is important to understand the socio-economic structure and linked to this, produce and implement consistent decisions.

The transition to machine-based agricultural production though causing labour in excess of requirements, leads to the excess labour force moving towards other areas of industry like production. Development of innovative technologies provides the opportunity for economic growth and enlarging market share. Economic gains providing expanding market share make it possible to develop by specializing on a regional basis and linked to this leads to more productive evaluation with specialized production models for regional areas.

As a result, the agricultural mechanization levels should be investigated locally and regionally, apart from in the country in general. Thus, the aim is not just to ensure success in targeting the economic gains mentioned above, but is also considered to be rapid and effective realization of sustainable agricultural

policies. In this study, the aim was to obtain basic values related to tractor use and agricultural tools-machines in Kırşehir province and to reveal criteria of current agricultural mechanization levels.

Agricultural mechanization criteria levels were:

- ***Mean tractor power*** 40.82 kW (lowest 27.47 kW in Akpınar, highest 52.38 kW in Kaman county);
- ***Mean tractor power per area worked*** 0.84 kWha^{-1} (lowest 0.63 kWha^{-1} in Çiçekdağı, highest 1.03 kWha^{-1}; in Mucur county),
- ***Mean area worked per tractor*** 53.16 ha/tractor (lowest 29.88 ha/tractor in Akpınar, highest 79.32 ha/tractor in Kaman county);
- ***Mean number of tractors per 1000 ha*** 22 (lowest 13 in Kaman, highest 34 in Akpınar county);
- ***Mean agricultural tools/machines per tractor*** 6 (lowest 5 in Akpınar, highest 9 in Çiçekdağı county);
- ***Mean number of combine harvesters per 1000 ha*** 2 (lowest 1 combine harvester per 2500 ha in Kaman, highest 3/1000 ha in Akpınar county);
- ***Area worked per combine harvester*** 895.3 ha (lowest 313.69 ha in Akpınar, highest 2564.5 ha in Kaman county).

Agricultural mechanization criteria for Turkey in general are as follows:

- Mean tractor power per area worked is 2.18 kWha^{-1};
- Mean area per tractor is 26 ha;
- Mean number of tractors per 1000 ha is 58;
- Mean number of agricultural tools/machines per tractor is 5.

Compared with the mean values for Turkey, the mean tractor power per operated area in Kırşehir province appears to be lower at 1.34 kWha^{-1}. While the mean area per tractor in Turkey is 26 ha, this value is 53.15 ha in Kırşehir. The mean number of tractors per 1000 ha in Turkey is 58, while this value is 22 for Kırşehir. The mean number of agricultural tools/machines per tractor in Turkey is 5, while this was found to be 6 in Kırşehir.

In this region with dominant rural sector, recommendations for decision-makers that require focus to bring the agricultural mechanization levels up to at least country level may be listed as follows:

- Investment in people and agricultural activities in rural areas;

- Implementation of policies needed to increase agricultural production yield;
- Ensuring increases in income and reducing poverty in the rural sector;
- Studies focus on optimal utilization of resources should be performed to introduce sustainable production methods into the region to ensure self sufficiency and sustainability [14].

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