Bozok Journal of Science
Volume 3, No 1, Page 1-9 (2025)
Review Article DOI: 10.70500/bjs.1618918

The Effects of Agricultural Machinery and End of Its Economic Life Tractors on The Environment

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Received: 13.01.2025 Accepted: 05.02.2025 Final Version: 11.04.2025

Abstract
Agricultural machinery stands out with its economic, environmentally friendly, and social features. and plays an important role in sustainable agricultural production, but if the necessary precautions are not taken, the use and maintenance of these machines can have negative effects on the environment. The use of tractors that have completed their economic life causes significant environmental pollution as well as financial losses. The oils used in agricultural machinery can pollute the aquatic environment and soil as waste oil after a while, and exhaust emissions can pollute the air. It can also have negative effects on human health. Therefore, waste oils should be disposed of with the most effective and standardized treatment methods. In this study, the effects of agricultural machinery and tractors that have completed their economic life on the environment were investigated, and solution suggestions were presented. The most important results of the study are that carbon emissions, energy consumption, and waste should be reduced by using modern technologies. A comprehensive incentive program should be implemented during the renewal process of the tractor park.

Keywords: Environment, Agricultural Tractors, Agricultural Machinery, Pollution

1. INTRODUCTION

Environmental problems have attracted more public attention in the last twenty years in the form of rapid urbanization, industrialization, air and water pollution, soil contamination and transportation. Factors such as technology's impact on human physical and socio-cultural environment, population explosion and unregulated urbanization have played an important role in the aggravation of environmental problems. Although environmental problems emerged earlier in developed countries, significant progress has been made in solving these problems thanks to the prosperity brought by economic growth. On the other hand, the importance of the problem is only now being understood in developing countries (Bilginoğlu, 1993).

Production techniques that include the use of agricultural machinery, pesticides and different fertilizers are imported from developed countries that produce the same product. Thus, the ecological system is damaged as a result of the careless use of technologies developed for a different production structure and a different environment in order to increase production (Hecht, 1985).

Throughout their lifespan, agricultural machinery can create environmental problems including energy consumption, emission pollution, solid waste and liquid waste (Çetin, 2011).

If the necessary investments in agricultural machinery are not made and the necessary importance is not given to information (TARMAKBIR, 2023);

- Decrease in yield and product quality,
- Pollution in water resources due to increased use of pesticides and fertilizers,
- Environmental problems caused by excessive use of chemical fertilizers, decreased product yield and quality,

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• Financial losses caused by destroying products after detecting pesticide residues in products,
• Pesticide residues increasing the possibility of birth defects, allergies, asthma, cancer, etc.,
• Decrease in profitability due to excessive use of inputs,
• Waste of water,
• Use of more pesticides, water, and chemical fertilizers making the soil infertile,
• Environmental problems caused by high carbon emissions,
• Increased product loss during harvest,
• Decrease in yield and quality in animal husbandry, increased possibility of disease,
• Increased possibility of products being affected by natural conditions,
• Increase in maintenance and repair costs,
• Increase in operating costs such as oil and fuel,
• Increase in the risk of malfunction, accident, injury, death, etc. may result.

According to 2023 data; 52.1% of the 2,186,150 tractors registered in Turkey are tractors over 21 years old. The average age of tractors is 24.4 (TUİK, 2023).

It is known that in the Turkish tractor park, there are tractors that are not in operation despite appearing in traffic records, as well as tractors that have been removed from traffic records but are still actively working. However, there are no official statistics on this issue (TARMAKBiR, 2023). The fact that old technology tractors are in majority in use increases both fuel consumption values and the amount of waste due to service operations.

In this study, the effects of agricultural machinery and tractors that have completed their economic life on water pollution, air pollution and soil pollution were investigated, and solution suggestions were presented. In addition, how they will affect public health was also discussed.

2. ENVIRONMENTAL EFFECTS OF USING TRACTORS THAT HAVE ENDED THEIR ECONOMIC LIFE

There is a rapid increase in the number of tractors in developed and developing countries of the world. According to TUIK data, the number of tractors in Turkey, which was 1,180,127 in 2002, increased to 2,265,267 in 2024 (TUİK, 2025). The increase in the number of tractors has also brought to the agenda the number of tractors that have completed their economic life, and the problems related to them.

The use of tractors that have completed their economic and mechanical life causes economic losses (increase in oil-fuel costs and maintenance-repair costs), work and time losses, product yield and quality losses due to work losses, environmental pollution and carbon social cost brought by more carbon emissions, toxic damages, excessive agricultural input usage due to decreased operator attention, deterioration of human health due to increased noise emissions, decrease in work efficiency, and loss of life and property due to increased accident risk. Gökdoğan (2012), stated that it would be appropriate to renew machines that have completed their economic life because their service costs will be high. Waste oils are produced during service maintenance and must be disposed of.

In a study conducted in the European countries called EU15, within the scope of the 'EU DG Environment A2SR Consumption and Waste' report, which includes EU countries on the recovery and evaluation of waste oils, it is stated that 65% of the machine oils used consist of motor vehicle waste oils. A large portion of the oils used in tractors are irreversibly carried to the combustion chamber by the piston rings in the cylinder during use and burned. Oil burning is especially high in tractors that are old, worn out and have completed their economic life (Çetin, 2011).

According to research, tractors that have reached the end of their useful life cause an average of 700 liters more fuel and 100-150 hours of work loss per year. Based on the average of exhaust emission measurements made with tractors that are 25+ years old, there is an additional 1,816 kg of CO emission for the 250 hours/year average work predicted for old tractors (Evcim, 2008). In light of this data, the losses caused by a tractor that has reached the end of its useful life are calculated according to current data and are given in Table 1 (TEPGE, 2021).

Table 1. Cost of losses caused by a tractor that has reached the end of its economic life

Casualties	Annual Cost (TL/tractor)
Fuel	4550
Maintenance and repair	2000
Job loss	9000
Carbon emission	344,43
Total	15894,43

According to statistical information from seven EU countries (Austria, Finland, France, Germany, Italy, Spain and the United Kingdom) taken from the Community Road Accident Database (CARE); tractors older than 12 years old are involved in 56% of road accidents resulting in injuries and 69% of road accidents resulting in deaths (CEMA, 2015). It is also known that 66% of tractors involved in injury and fatal accidents in Turkey are older than 10 years old (TARMAKBİR, 2023).

In addition to the aforementioned economic losses, the use of end-of-life tractors causes considerable environmental pollution. It is accepted that environmental pollution created for different reasons in the EU and some developed countries has social costs. The most important problem in the operation of the carbon emission and trading system is measuring the economic cost of climate change. In this measurement, a calculation method called the "social cost of carbon" is used. The social cost of carbon is calculated as the net present value of the effect of each additional ton of carbon released into the atmosphere for 100 years or more on climate change. The average cost of this is $43 per ton of carbon (Tunahan, 2010; Watkiss and Downing, 2008). However, deviations from this average are quite high; in various analyses, the value in question varies from $10 to $350 (Tunahan, 2010).

The average tractor life is 10-12 thousand hours in international standards. Since the annual tractor usage period in Turkey is around 500 hours (Evcim and Ertuğrul, 2017), the maximum tractor life can be accepted as 24-25 years. This shows that half of the tractor fleet in Turkey has exceeded the economic usage limit (TARMAKBİR, 2023).

The financial losses caused by working with tractors that have long outlived their useful life are also known by farmers, but they cannot be taken into account due to insufficient income. On the other hand, some farmers use their tractors as a borrowing tool to meet their financial needs, renew their tractors that have not yet completed their economic life through exchange, and take out long-term loans. This situation brought about by economic problems, on the one hand, pushes farmers into debt, and on the other hand, causes second-hand tractor prices to rise far above their real values, thus causing the tractor renewal process to lose its usual dynamism and suppressing the demand for new tractors (TARMAKBİR, 2023).

Approximately 1.3 million of the tractors were manufactured before the date of entry into force of Phase 1 level engines of the "2000/25/EC, Type Approval Directive on Measures to be Taken Against Gas Emissions and Particulate Pollutants from Engines Designed to Drive Agricultural or Forestry Tractors" (01/1/2007). Approximately 1.3 million tractors that are not included in any defined engine emission level are currently in the field in Turkey (TARMAKBİR, 2023). Two examples are worth examining to get an idea of the magnitude of their emissions (Figure 1).

In India, the Phase 1 level tractors, which came into force in 1999, have 14 g/kWh CO, 3.5 g/kWh HC, and 18 g/kWh NOx values (Shao, 2016). When these values are taken into account, there is an emission of 530,000 tons of pollutants for 1.3 million Phase 0 level tractors (average tractor power is 46 kW and 250 hours/year is taken into account) (TARMAKBİR, 2023).

In the European Union, the Euro 0 implemented between 1988 and 1992 for N3 category freight trucks has the values of 12.3 g/kWh CO, 2.6 g/kWh HC, and 15.8 g/kWh NOx. According to these values, there is a pollutant emission of 458 thousand tons for 1.3 million Phase 0 level tractors (average tractor power of 46 kW and 250 hours/year are considered) (TARMAKBİR, 2023).

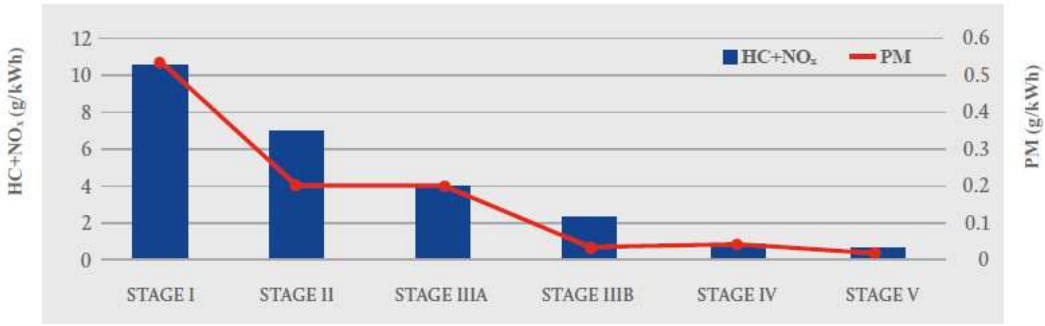

Figure 1. Emission limits for phase levels (TARMAKBİR, 2023).

3. EFFECTS OF AGRICULTURAL MACHINERY ON WATER AND SOIL POLLUTION

The waters on earth are in a continuous cycle. After the waters are used for human needs, they are taken from this cycle and given back to the same cycle. As a result of this continuous cycle; substances mixed into the water change the physical, chemical and biological properties of the water, creating the situation called "water pollution". Water pollution is defined as the negative change in the physical, chemical, bacteriological, radioactive and ecological properties of the water source.

A wide range of waste products are produced in private or authorized services where maintenance, repair and service of agricultural machinery are carried out. These products, which also pose a danger in the workplace, can be listed as fuel (gasoline, LPG or diesel), engine oil, gearbox oil and hydraulic oil (Borat et al., 1992; Wilfried, 1995).

Mineral oils or various synthetic oils used in the motor vehicle sector, especially for lubrication purposes, become chemically and physically dirty after a certain period of use. They lose their properties and must be changed at periodic intervals. Waste oils are very dangerous and should not be poured into soil or water because they pollute the environment and harm living creatures.

One liter of used motor oil makes 1 million liters of water unusable and 5 million liters of water undrinkable (Çetin, 2011).

Waste oils are wastes with high calorific value. When waste oils are burned by unconscious and unauthorized people using inappropriate methods, heavy metal and chlorine compounds found in the structure of the waste oil are released into the atmosphere. The released particulate matter, carbon monoxide, organic pollutants and metal emissions pollute the air we breathe.

If waste oils are spilled on the soil or reach the soil in some way, it causes the structure of the soil to deteriorate and its productivity to be lost. It harms the plants on the soil surface. Since the soil has a permeable structure, waste oils mix with groundwater and pollute our water resources (Artemis Arıtım).

Discharging waste oils into the sewage system causes the pipes to narrow and the sewage system to become clogged by 40%, damaging the operation of the system, increasing maintenance and repair costs and reducing the service life of the system equipment (Artemis Arıtım).

Nowadays, especially in countries that are developed in agriculture, reduced tillage or no-tillage farming methods, which are among the conservation tillage systems, have started to gain importance. While in traditional tillage systems, intensive and deep tillage of soils with ploughs causes many negative effects on the physical, chemical and biological properties and causes problems in soil ecosystems, some studies have shown that significant positive developments are achieved in both the environment and soil quality properties in conservation or reduced tillage systems (Barut et al., 2010).

Field traffic is the main cause of soil compaction. When the water content of the soil is high, agricultural activities further increase compaction. In compacted soils, significant changes occur in physical and mechanical properties starting from the compaction surface to a certain profile depth. While there are increases in bulk density and penetration resistance values, there are decreases in the proportional amounts of total porosity, void ratio, aeration and drainage pores. In enterprises that carry out intensive agricultural production, the field surface is exposed to more wheel tracks than 4-5 times its area in a production year. Changes in soil properties

show significant changes depending on the texture of the soil, its water content, the weight of the pressurizing tool, and the duration of the press (Şeker and Işıldar, 2000).

The distribution of pore sizes in a soil profile has an important effect on studies on plant growth, soil erosion and drainage. The decrease in the total porosity of the soil and the proportional amount of large pores negatively affects the development of plant roots and adequate aeration. In bottom lands, soil compaction creates drainage problems, and in sloping areas, it increases surface runoff and causes erosion (Şeker and Işıldar, 2000).

‘‘Soil; is an indispensable natural resource, together with air and water, for the survival of living natural resources. Soil pollution is the deterioration of the physical, chemical, biological and geological structure of the soil as a result of human activities. It is stated that the pollution in question occurs as a result of wrong agricultural techniques, wrong and excessive use of fertilizers and agricultural pesticides, and the release of waste and residues, toxic and hazardous substances into the soil’’ (İkincikarakaya et al., 2013).

4. EFFECTS OF AGRICULTURAL MACHINERY ON AIR POLLUTION

Air pollution is the transformation of pollutants such as dust, gas, smoke, odor, and water vapor into a structure that harms living things by disrupting the natural composition of the air. The harmful effects of more than one pollutant gas on the environment and especially on agricultural products can be several times greater than the total damage caused by individual pollutants (İkincikarakaya et al., 2013).

Air pollution has negative effects on human health, visibility, plants and animal health. Smoke, which is a gas mixture of solid and liquid particles resulting from the incomplete combustion of carbonaceous materials such as solid fuels and fuel oil, is a type of air pollution and has a reducing effect on visibility. Air pollution also has a destructive and disruptive effect on artistic and architectural structures. It can be lethal and prevent growth on plants. For this reason, air pollution is harmful both in terms of the health of living things and economically (Bai et al., 2019; Bollen, 2015; Durgut, 2024). Accordingly, in many European countries, environmental protection due to air pollution is one of the most important issues. Research conducted in Switzerland has shown that non-road traffic is the cause of a significant portion of air pollution (Rinaldi, 2000; Sağlam et al., 2017).

In the field of agricultural machinery, some studies have been conducted by researchers from the United States and European countries to measure the exhaust gas emissions of tractors using PEMS (Portable Emission Measurement System) equipment. These studies reported that tractors have higher air pollutant emissions (CO, CO, NOx, HC, and PM) than passenger vehicles (Chen et al., 2023; Durgut, 2024; Kim et al., 2024). Due to the negative impact of these emissions on the environment, it has been proven that it is necessary to legally limit the amount of pollutants produced by the engine (Kotus et al., 2013).

Previous studies have shown that the emission rates of pollutants from agricultural machinery vary greatly under different operating conditions (Fu et al., 2013; Ge et al., 2013; Hou et al., 2019; Ji, 2015).

In our country, emission standards for non-road engines have been adopted by the Ministry of Science, Industry and Technology (from the Ministry of Science, Industry and Technology). The standards have been harmonized with the EU's non-road mobile machinery regulations (NRMM) (Resmî Gazete, 2020).

Despite significant progress in exhaust emission measurements, legislation regulating exhaust gas emissions from off-road engines to further reduce pollutants released into the atmosphere is still under development. Continuous research is needed on technical solutions for reducing emissions and their application to agricultural tractors. Measuring fuel consumption and pollutant emissions in the field is an important step. This step will definitely be useful for environmental assessments of agricultural production using the LCA (Life Cycle Analysis) approach, which is increasingly adopted in the assessment of environmental sustainability of products and services in agriculture (Canoğlu et al., 2020; Durgut, 2024; Erisman et al., 2008; EEA, 2023; Faria et al., 2006).

5. EFFECTS OF AGRICULTURAL MACHINERY ON HUMAN HEALTH

Metal emissions that may occur as a result of burning waste oils may cause acute or chronic health effects on humans. The accumulation of metals released in the body due to inappropriate combustion conditions may pose a danger to human health. The accumulation of metals released into the atmosphere on particles smaller than 1 μm in diameter facilitates their reaching the lungs through respiration.

The metal emissions that may occur as a result of burning waste oils may reach the air environment directly through inhalation or indirectly through ecological cycles, posing a health threat to humans (Bolat et al., 2016; Kampa and Castanas, 2008; Nerin et al., 2000).

Carbon monoxide is a colorless, tasteless, odorless gas that is released as a result of incomplete combustion of carbon-containing compounds such as diesel or gasoline in vehicle engines. Carbon monoxide passes into the blood after inhalation, prevents oxygen from binding to hemoglobin in erythrocytes, oxygen cannot be transported to the tissues and hypoxia occurs (İbadullayeva et al., 2019).

Air pollutants damage epithelial cells in the respiratory tract, increasing epithelial permeability and leading to a series of inflammatory events such as inflammatory cell migration and increased cytokines. Air pollution causes retardation in lung development, decreased respiratory functions, increased respiratory symptoms, and exacerbation of asthma and chronic obstructive pulmonary disease (COPD) (İbadullayeva et al., 2019).

6. CONCLUSION AND RECOMMENDATIONS

Carbon emissions, energy consumption, and waste should be reduced by using modern technologies. Ways to reduce carbon emissions at every stage of agricultural production should be sought. The additional costs of a carbon tax should be revealed (TARMAKBİR, 2023).

Renewal of tractors that have completed their economic life is important in terms of mechanization due to their high maintenance and repair costs, as well as their technological inadequacy in agricultural operations and the damage they cause to the environment (Evcim et al., 2020). In order to solve the problem, the park's renewal process must be brought to its own dynamics with a comprehensive incentive program (TARMAKBİR, 2023).

When waste oils are discharged into the sewerage network in an uncontrolled manner, they can cause water pollution. Waste oils should be disposed of safely or used in a way that will not harm people, living beings or natural life. In order to reduce and prevent water pollution, the widespread use of treatment facilities should be encouraged. Considering that the chemicals formed as a result of burning waste oils in uncontrolled energy production processes cause air pollution, precautions should be taken. Strict sanctions should be imposed on individuals or organizations that release waste oils from agricultural machines into the natural environment without disposing of them.

Waste management and facilities should be considered together, and incentives should be given, and public institutions should work in coordination. Economic analyses should be well-conducted in the environmental protection activities of small-scale agricultural enterprises.

Although there are sufficient laws in national and international legislation to prevent environmental pollution, since implementation is difficult, authority and responsibility should be gathered in a single organization (Çetin, 2011).

With the development of environmental awareness, Turkey should aim to prevent environmental and water pollution at its source and reduce the effects that will occur during production or maintenance service operations to minimum levels (Çetin, 2011).

In-service training should be provided for agricultural machinery manufacturers, farmers and non-governmental organizations. Sustainable environmental education programs should be organized as a society under the responsibility of local governments. Measures will be taken to prevent pollution of the environment.

AUTHOR'S CONTRIBUTIONS

The authors contributed equally.

CONFLICTS OF INTEREST

There is no conflict of interest.

RESEARCH AND PUBLICATION ETHICS

The author declares that this study complies with Research and Publication Ethics.

REFERENCES

Artemis Arıtım, "Atık yağların çevreye etkisi," https://www.artemisaritim.com/atik-yaglarin-cevreye-etkisi [Access Date: 29-September-2024].

Bai, L., Jiang, L., Yang, D. Y., & Liu, Y. B. (2019). Quantifying the spatial heterogeneity influences of natural and socioeconomic factors and their interactions on air pollution using the geographical detector method: A case study of the Yangtze River Economic Belt, China. Journal of Cleaner Production, 232, 692-704. Doi: 10.1016/j.jclepro.2019.05.342

Barut, Z. B., Çelik, İ., & Turgut, M. M. (2010). Buğday tarımında farklı toprak işleme sistemlerinin toprağın bazı fiziksel özelliklerine etkisi. *Tarım Makinaları Bilimi Dergisi*, *6*(4), 237-246.

Bilginoğlu, M. A. (1993). Çevre sorunları ve çözüm yolları. *Erciyes Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, (10), 59-75.

Bolat, D., Can-güven, E., Gedik, K., & Kurt-karakuş, P. (2016). Yağ sektörü ürün veya atıklarının alternatif yakıt olarak kullanılmasının çevre ve insan sağlığı üzerine etkileri. *Uludağ Üniversitesi Mühendislik Fakültesi Dergisi*, *21*(1), 25-44.

Bollen, J. (2015). The value of air pollution co-benefits of climate policies: analysis with a global sector-trade CGE model called WorldScan. *Technological Forecasting and Social Change*, *90*, 178-191. Doi: 10.1016/j.techfore.2014.10.008

Borat, O., Balcı, M., & Sürmen, A. (1992). *Hava kirlenmesi ve kontrol tekniği*. Teknik Eğitim Vakfı.

CEMA, "Eurepean Agricultural Machinery Asssociation. Road accidents with tractors: main problem is older machinery. 2015," https://www.cema-agri.org/images/publications/press_releases/Press_Release_CEMA-EU_Tractors_Accident_Database_17_07_2015.pdf [Access Date: 29-September-2024].

Chen, Y., Zhao, Z., Yi, W., Hong, J., & Zhang, B. (2023). Has China achieved synergistic reduction of carbon emissions and air pollution? Evidence from 283 Chinese cities. *Environmental Impact Assessment Review*, *103*, 107277. Doi: 10.1016/j.eiar.2023.107277

Canoğlu, S., Önal, Ş., Bilgen, H., Demir, V., & Yazgı, A. (2020). Tarım makinaları sanayinde mevcut durum ve gelecek. *Türkiye Ziraat Mühendisliği IX. Teknik Kongresi Bildiriler Kitabı-1*, 233.

Çetin, M. (2011). Çevre ve su kirliliğinde makine yağları, çevre etkileri ve çözüm önerileri. *Tarım Bilimleri Araştırma Dergisi*, (1), 41-47.

Durgut, M. R. (2024). Çevre kirliliği açısından traktör egzoz emisyon test yöntemlerinin önemi. *Turkish Journal of Agriculture-Food Science and Technology*, *12*(7), 1197-1203. Doi: 10.24925/turjaf.v12i7.1197-1203.6835

EEA, "EMEP/EEA air pollutant emission inventory guidebook 2023," https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023. [Access Date: 29-September-2024].

Erisman, J. W., Bleeker, A., Hensen, A., & Vermeulen, A. (2008). Agricultural air quality in Europe and the future perspectives. *Atmospheric Environment*, *42*(14), 3209-3217. Doi: 10.1016/j.atmosenv.2007.04.004

Evcim, H. Ü. (2008). Türkiye Traktör Parkı (2007), *Türk Traktör ve Zir. Mak. AŞ.* Ankara, *(Yayımlanmamış Araştırma Raporu)*.

Evcim, H. Ü., & Ertuğrul, G. Ö. (2017). Türkiye tarımında traktör kullanımı (2010). *Tarım Makinaları Bilimi Dergisi*, *13*(1), 21-31.

Evcim, H.Ü., Yazgı, A., Gülsoylu, E., Aykas, E., Çakmak, B., Demir, V., Yürdem, H., Güler, H., Urkan, E., Alayunt, F., Yalçın, H., Bilgen, H., Günhan, T. (2020). Tarımsal mekanizasyonda mevcut durum ve gelecek, Türkiye Ziraat Mühendisliği IX. Teknik Kongresi (pp. 497-526) Ankara, Türkiye.

Faria, N. M. X., Facchini, L. A., Fassa, A. G., & Tomasi, E. (2006). Farm work, dust exposure and respiratory symptoms among farmers. *Revista de saude publica*, *40*, 827-836. Doi: 10.1590/S0034-89102006005000006

Fu, M., Ding, Y., Yin, H., Ji, Z., Ge, Y., & Liang, B. (2013). Characteristics of agricultural tractors emissions under real-world operating cycle. *Transactions of the Chinese Society of Agricultural Engineering*, *29*(6), 42-48.

Ge, Y., Liu, H., Ding, Y., Yin, H., Fu, M., & Li, J. (2013). Experimental study on characteristics of emissions and fuel consumption for combines. *Transactions of the Chinese Society of Agricultural Engineering*, *29*(19), 41-47.

Gökdoğan, O. (2012). Isparta ilindeki tarımsal işletmelerin tarımsal yapısı ve mekanizasyon özellikleri. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, *9*(2), 13-17.

Hecht, S. B. (1985). Environment, development and politics: capital accumulation and the livestock sector in eastern Amazonia. *World development*, *13*(6), 663-684.

Hou, X., Tian, J., Song, C., Wang, J., Zhao, J., & Zhang, X. (2019). Emission inventory research of typical agricultural machinery in Beijing, China. *Atmospheric Environment*, *216*, 116903.

İbadullayeva, J., Jumaniyazova, K., Azimzadeh, S., Canıgür, S., & Esen, F. (2019). Çevre kirliliğinin insan sağlığı üzerindeki etkileri. *Türk Tıp Öğrencileri Araştırma Dergisi*, *1*(3), 52-58.

İkincikarakaya, S. Ü., Beyaz, K. B., & Rezaeı, F. (2013). Doğal kaynaklar ve tarım. *Türk Bilimsel Derlemeler Dergisi*, (1), 104-109.

Ji, Y. (2015). Development of an air pollutant emission inventory for Beijing and preliminary study of haze weather. *Beijing Jiaotong University*.

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environmental pollution*, *151*(2), 362-367.

Kim, W. S., Baek, S. M., Baek, S. Y., Jeon, H. H., Siddique, M. A. A., Kim, T. J., ... & Kim, Y. J. (2024). Evaluation of exhaust emissions of agricultural tractors using portable emissions measurement system in Korean paddy field. *Scientific Reports*, *14*(1), 3491.

Kotus, M., Pexa, M., & Kubín, K. (2013). Modelling of non-road transient cycle. *Journal of Central European Agriculture*. Doi: 10.5513/jcea.v14i4.2327

Nerin, C., Domeno, C., Moliner, R., Lazaro, M. J., Suelves, I., & Valderrama, J. (2000). Behaviour of different industrial waste oils in a pyrolysis process: metals distribution and valuable products. *Journal of Analytical and Applied Pyrolysis*, *55*(2), 171-183.

Resmî Gazete, "Karayolu dışında kullanılan hareketli makinalara takılan içten yanmalı motorlar için gaz ve partikül halindeki kirletici emisyon sınırları ve tip onayı ile ilgili gereklilikler hakkında yönetmelik (2016/1628/AB), 2020" https://www.resmigazete.gov.tr/eskiler/2020/09/20200911-3.htm. [Access Date: 29-September-2024].

Rinaldi, M. (2000). Consumption and emission factors of tractors for various farming tasks. *AgEng Paper 00-PM-003*.

Sağlam, C., Çetin, N., & Kuş, Z. A. (2017). Kayseri İlinde Meydana Gelen Traktör ve Tarım Makinaları Kazalarının Değerlendirilmesi. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*, *6*(Özel Sayı (BSM 2017)), 20-34.

Shao, Z. (2016). An emissions inventory for agricultural tractors and construction equipment in India. International Council of Clean Transportation.

Şeker, C., & Işıldar, A. A. (2000). Tarla trafiğinin toprak profilindeki gözenekliliğe ve sıkışmaya etkisi. Turkish Journal of Agriculture and Forestry,24(1), 71-77.

TARMAKBİR, "Tarım ve Makine Sanayi Etkileşimi Raporu, 2023," https://www.makinebirlik.com/images/d/library/c2003bd1-81da-452c-bd11-90bb755447c2.pdf [Access Date: 29-September-2024].

TEPGE, "Türkiye'de tarımsal mekanizasyon düzeyi, sorunları ve çözüm önerileri 2021," https://arastirma.tarimorman.gov.tr/tepge/Belgeler/Di%C4%9Fer%20Yay%C4%B1nlar/T%C3%BCrkiyede%20Tar%C4%B1msal%20Mekanizasyon%20D%C3%BCzeyi,%20Sorunlar%C4%B1%20ve%20%C3%87%C3%B6z%C3%BCm%20%C3%96nerileri%202021-346%20TEPGE.pdf [Access Date: 01-October-2024].

TUİK, "Motorlu kara taşıtları, 2023," https://data.tuik.gov.tr/Bulten/Index?p=Motorlu-Kara-Ta%C5%9F%C4%B1tlar%C4%B1-Aral%C4%B1k-2023-49432&dil=1 [Access Date: 29-September-2024].

TUİK, "Motorlu kara taşıtları, 2025," https://biruni.tuik.gov.tr/bolgeselistatistik/tabloOlustur.do. [Access Date: 30-January-2025].

Tunahan, H. (2010). Küresel iklim değişikliğini azaltmanın bir yolu olarak karbon finansmanı. Muhasebe ve Finansman Dergisi, (46), 199-215.

Watkiss, P., & Downing, T. (2008). The social cost of carbon: Valuation estimates and their use in UK policy. Integrated Assessment Journal, 8(1).

Wilfried., S. (1995) Motorculukta metal tekniği. Ankara: MEB