KSÜ Tarım ve Doğa Derg 28 (6), 1445-1457, 2025
KSU J. Agric Nat 28 (6), 1445-1457, 2025
https://doi.org/10.18016/ksutarimdoga.vi.1623025

The Impact of the Transformation of Agricultural Lands into Urbanized Areas on Micro-Scale Air Pollutants: The Case of Yalıncak, Trabzon

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ABSTRACT
Soil is a vital non-renewable resource and the main basis of agriculture. However, urbanization and growing non-agricultural demands are steadily reducing agricultural lands. This situation brings with it many environmental problems, especially in cities, and leads to deterioration of air quality at micro and macro scales. One of the important functions of agricultural soils is to store large amounts of carbon through organic matter accumulation. Agricultural areas help improve air quality by limiting wind-borne dust and particulates. The study area was agricultural land prior to 2009. However, half of the study area was opened to construction and currently provides mass housing services. Within the scope of the research, pollutant (PM2.5, PM10, CO, CO2) measurements were made in both study areas, and the obtained data were compared, and the effect of agricultural areas on micro air quality was examined. According to the obtained results, it was observed that carbon monoxide (CO) and carbon dioxide (CO_2) levels in agricultural areas were lower compared to constructed areas. CO levels were measured between 1.09 µg m^{-3} and 2.87 µg m^{-3} in agricultural areas and between 2.09 µg m^{-3} and 2.98 µg m^{-3} in built-up areas. Similarly, thanks to agricultural vegetation, CO_2 levels remained between 251.47 µg m^{-3} and 429.97 µg m^{-3} in agricultural areas and between 411.75 µg m^{-3} and 520.59 µg m^{-3} in built-up areas. These findings indicate that agricultural lands enhance carbon absorption, reduce particulate matter, and are vital for sustainable urbanization.

Agricultural Structures and Irrigation

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 19.01.2025
Kabul Tarihi : 16.05.2025

Anahtar Kelimeler
Land use land cover
Agricultural land use
Air quality
Mikro air quality
Agricultural landscape

Tarımsal Alanların İmarlaşmaya Dönüşümünün Mikro Ölçekli Hava Kirleticiler Üzerindeki Etkisi: Trabzon Yalıncak Örneği

ÖZET
Yenilenemeyen kaynaklar arasında yer alan toprak, yaşamın vazgeçilmez bir parçası olup, tarımın en önemli hammaddesidir. Ancak, kentleşme ve tarım dışı kullanımlar için cazibe merkezi haline gelmesi, tarım arazilerinin giderek azalmasına neden olmaktadır. Bu durum, özellikle kentlerde çevresel birçok sorunu beraberinde getirmekte, mikro ve makro ölçeklerde hava kalitesinin bozulmasına yol açmaktadır. Tarım topraklarının önemli işlevlerinden biri, organik madde birikimi yoluyla büyük miktarda karbon depolamaktır. Ayrıca, tarım alanları rüzgarla taşınan toz ve partikül madde miktarını azaltarak hava kalitesine olumlu katkıda bulunmaktadır. Bu çalışma kapsamında seçilen arazi, 2009 ve öncesinde tarım alanı olarak kullanılmıştır. Ancak, çalışma alanının yarısı, yapılaşmaya açılarak günümüzde toplu konut hizmeti vermektedir. Araştırma kapsamında her iki çalışma alanında da kirletici madde (PM2.5, PM10, CO, CO2) ölçümleri yapılmış ve elde edilen veriler karşılaştırılarak tarım alanlarının mikro hava kalitesine etkisi incelenmiştir. Elde edilen sonuçlara, göre tarımsal alanlarda karbon monoksit (CO) ve karbon dioksit (CO_2) seviyelerinin, yapılaşmış alanlara kıyasla daha düşük olduğu görülmüştür. CO seviyeleri tarım alanlarında 1,09 µg m^{-3} ile 2,87 µg m^{-3} arasında, yapılaşmış alanlarda ise 2,09 µg m^{-3} ile 2,98 µg m^{-3} arasında ölçülmüştür. Benzer şekilde, tarımsal bitki

Tarımsal Yapılar ve Sulama

Research Article

Article History
Received : 19.01.2025
Accepted : 16.05.2025

Keywords
Arazi kullanımı arazi örtüsü
Tarımsal arazi kullanımı
Hava kalitesi
Mikro hava kalitesi
Tarımsal peyzaj

örtüsü sayesinde CO_2 seviyeleri tarım alanlarında 251,47 µg m^{-3} ile 429,97 µg m^{-3} arasında kalırken, yapılaşmış alanlarda 411,75 µg m^{-3} ile 520,59 µg m^{-3} arasında ölçülmüştür. Bu sonuçlar, tarım arazilerinin karbon emilimini artırarak ve partikül madde konsantrasyonlarını azaltarak çevresel fayda sağladığını ve sürdürülebilir şehirleşme için kritik bir rol oynadığını ortaya koymaktadır.

Atıf Şekli: Onur, M., (2025) Tarımsal Alanların İmarlaşmaya Dönüşümünün Mikro Ölçekli Hava Kirleticiler Üzerindeki Etkisi: Trabzon Yalıncak Örneği. *KSÜ Tarım ve Doğa Derg 28* (6), 1445-1457. https://doi.org/10.18016/ksutarimdoga. vi. 1623025.

To Cite : Onur, M. (2025) The Impact of the Transformation of Agricultural Lands into Urbanized Areas on Micro-Scale Air Pollutants: The Case of Yalıncak, Trabzon. KSÜ Tarım ve Doğa Derg 28 (6), 1445-1457. https://doi.org/10.18016/ksutarimdoga. vi. 1623025.

INTRODUCTION

Soil is one of the essential elements of life and a limited natural resource that cannot be manufactured or renewed.

In addition to being a vital nutrient source for plants and a growth medium for forests and pastures, soil also serves as a foundation for industrial and residential developments and as a raw material for various industries. Therefore, soil is an indispensable production element for the agricultural sector, as well as being of great importance for non-agricultural sectors (Topcu, 2012). 40% of the world's land surface is covered by agricultural landscapes (Vialatte et al., 2019). Factors such as industrial development, technological developments, rural-urban migration, and population growth have caused the reshaping of agricultural areas (Chen et al., 2024). Agricultural areas have many benefits in terms of culture, ecology, aesthetics, and even socio-cultural aspects (Guneroglu, Bekar 2016). Rapid population growth has accelerated rural-to-urban migration. In recent years, however, the phenomenon known as "urban sprawl" has increasingly emerged due to factors beyond population growth alone.

These include shifts in supply and demand, economic development, and changing living standards (Akseki, Meşhur, 2013). In this case, it paves the way for more energy consumption, misuse, degradation of the natural ecosystem, habitat destruction, and even opening up to construction in the long term (Barnes et. al. 2001; Bruegmann, 2005; Akseki and Meşhur 2013, Gulpinar Sekban and Acar 2024a; Gulpinar Sekban and Acar 2024b). Today, increasing urbanisation and industrialisation, together with climate change (Gulpinar Sekban and Bekar, Acar, 2019; Gulpinar Sekban and Düzgüneş, 2021) lead to significant deterioration in air quality. Especially the transformation of agricultural areas into impermeable surfaces deepens environmental problems and has negative effects on human health. With the increase in population, the need for agricultural products has increased (Song, 2002). However, in proportion to this increase, demands and needs, especially the need for shelter, have increased. In this process, agricultural areas within the city have become attractive places for investors and decision-makers. While trying to meet a need arising from need, the quality of clean air that is also needed is also damaged.

However, in this changing system, with the increasing needs, agricultural lands are gradually decreasing, they are used for purposes other than their intended purpose, and are replaced by impermeable surfaces. This changes the ecological balance while trying to meet some of the needs of the society. Habitat destruction, agricultural lands becoming less resistant, and the inability to absorb rainwater are just some of these problems (Fatima et. al., 2024). This process can be briefly defined as the transformation of natural living spaces into residential areas. The changing "urban agricultural areas", which are gradually disappearing from the cities, have a feature that improves micro air quality. With the change of agricultural areas, harmful emission releases increase within the city. Changes in land cover driven by human and natural factors play an important role in AQ control (Hua et. al., 2018; Pielke et. al., 2011; Saha et. al., 2024). Among the most critical concerns of the changing world order and rapidly growing world economy are climate change, carbon emissions, the rate of fossil fuel consumption, and air pollution (Xu et. al., 2022). The atmosphere is polluted and threatens the future due to the non-stop emission production of mankind for its own welfare. These emerging threats lead to a reduction in life expectancy (Remy et. al., 2011; Lelieveld et. al., 2015; Tomson et. al., 2021).

Unsustainable planning and management policies often promote excessive air pollution. Ambient air pollution has become a public health problem due to its impact on mortality. It is estimated that seven million people die annually due to the combined effects of indoor and outdoor air pollution (WHO, 2014). Air Quality Index (AQI) plays an important role in the assessment and prediction of air pollution. In recent years, studies on air pollution have mainly focused on the characteristics of the spatial and temporal distribution of pollutants in a particular area (Liu et al., 2024).

Air pollution is very important in measuring environmental sustainability as it affects public health and quality of life (Saha et al., 2024). Numerous studies have aimed to reveal the effective factors and driving mechanisms in the field of air quality. These studies usually combine traditional forecasting methods with the latest machine learning techniques to estimate air pollution levels (Donnelly et al., 2015; Yao et al., 2023; Liu et al., 2024). Globally, various policies have been implemented to protect agricultural lands from non-agricultural uses. For example, in the United States, the Soil Conservation and Domestic Allotment Act (1935) and the Farmland Protection Policy Act (FPPA) have established frameworks to prevent the misuse of agricultural land. Similarly, Canada enacted the Agricultural Rehabilitation and Development Act (ARDA) in 1961, which led to the development of the Canada Land Inventory (CLI)—a resource for guiding land-use decisions based on suitability for agriculture, forestry, recreation, and wildlife (Topcu, 2012). These examples highlight the importance of integrating land protection strategies into broader environmental planning efforts.

The main purpose of this study is to comprehensively examine the effects of the transformation of agricultural lands into impermeable surfaces on micro air quality. This study aims to reveal the impact of the conversion of agricultural lands into built-up areas on micro-scale air quality through quantitative data. It is aimed to determine how the physical and chemical processes that occur with the reduction of agricultural lands affect air quality at the micro scale and the potential consequences of this change on human health, especially on micro air quality. In this direction, emission measurements will be made on the determined study area, and the difference will be revealed with numerical data. These results will be evaluated, and the contribution of agricultural lands, especially to local air pollution levels, will be analyzed. The study aims to contribute to the development of strategies for the sustainable protection of agricultural landscapes and minimizing the effects of impermeable surface transformation.

MATERIAL and METHOD

Study Area Description

Trabzon is an important coastal city with a population of 824,352 (URL-1) located in the Black Sea Region of Turkiye. Geographically, it is located on the eastern coast of the Black Sea and is located between 40°59′ north latitude and 39°43′ east longitude. Trabzon is surrounded by the Black Sea to the north and the Eastern Black Sea mountain range extends to the south. These mountains significantly affect the climate and agricultural activities of the region (Figure 1).

Figure 1. Study area (Climate Change Knowledge Portal)
Şekil 1. Çalışma alanı (Climate Change Knowledge Portal)

Reason for Selection of Study Area

The vegetation of Trabzon consists mainly of tree species such as "spruce, beech, alder, fir, Scots pine, chestnut, oak, hornbeam, acacia, and maple". Rhododendron, which spreads widely in the lower layer of forested areas, is one of the prominent plants of the region. In addition, "blackberry, laurel, cherry laurel, and various herbs" are other plant species that attract attention in meadows and pastures. The agricultural identity of the region is identified with tea and hazelnuts. In addition to these, different field crops, vegetables, and fruits are also widely grown in the region (TC Ortahisar District Governorship, 2025).

Due to its rich nature and floristic diversity, Trabzon is a very rich province in terms of agricultural lands. Agricultural lands, which were 944251 hectares in 2019, 951974 hectares in 2020, 951974 hectares in 2020, 947514 hectares in 2021, and 1063286 hectares in 2022, turned into 1066742 hectares in 2023. This result shows that agricultural lands in Trabzon increased by 12.97% from 2019 to 2023 (Figure 2) (TUIK, 2025).

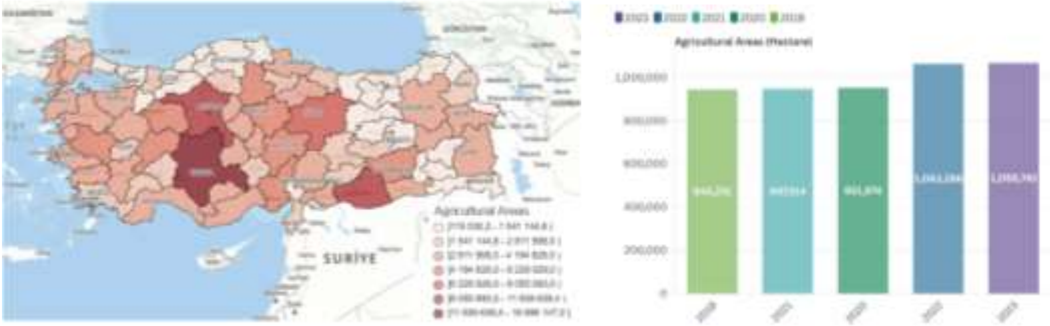

Figure 2. Agricultural land distribution of the study area by years (TUIK, 2025).
Şekil 2. Çalışma alanının yıllara göre tarımsal arazi dağılımı (TUIK, 2025).

This study was carried out on an area of 38,997 square meters located in the Yalıncak district of Trabzon province. Hazelnut (Corylus colurna), one of the most important plants that constitute the agricultural identity of the region and is considered one of the leading agricultural products of Turkiye in terms of economic value, is the most important plant in the study area. The hazelnut plant is a product integrated with the ecological, economic, and cultural structure of the region and has a critical role in the agricultural sustainability of the Black Sea Region. The research area was used intensively for hazelnut production as an active agricultural area in 2009 and before. However, there was a rapid change in land use in the region between 2009 and 2025, and during this process, agricultural lands largely turned into impermeable surfaces. During this process, agricultural activities were gradually replaced by impermeable surfaces and construction (Figure 3). This transformation process had significant effects not only on agricultural production, but also on ecosystem services and micro-air quality.

Methodology

The method consists of 3 stages within the scope of the study. In the first stage of the study, Land Use Land Cover (LULC) change analysis was performed using time series (2009, 2013, 2015, 2018, 2021, and 2023) obtained from Google Earth Pro satellites.

In the second phase of this study, measurements were made regarding micro air quality. In order to determine micro air quality, carbon monoxide (CO), carbon dioxide (CO_2), fine particulate matter ($PM_{2.5}$), and coarse particulate matter (PM_{10}) emissions were measured. These measurements were carried out by dividing the study area into 100 m^2 measurement networks. The area was divided into two parts: the first part is the agricultural land that is still in operation, and the second part is the part that has transformed from agricultural land to impermeable surfaces. Emission measurements were made separately for both regions, and the differences between these regions were compared. While the measurements made in the agricultural land revealed the effects of the microclimate shaped by the vegetation and soil, the effects of this transformation on micro air quality were examined in the area that has transformed into impermeable surfaces. The aerial photograph of the area was defined in the ArcGIS projection system, and the grids were created as 10x10m, 100 m^2. This ratio has been found to be a reliable ratio considering the measurements and land size (Werner, 2001; Kotharkar and Bagade, 2018; Quan and Bansal, 2021). Emission measurements will be conducted using coordinates determined from aerial photographs scaled in GIS and ArcMap software. Each frame's location will be confirmed in the field via GPS. Measurements will always start and end at the same coordinate points to minimize time-related differences and ensure consistency. Emission values (CO, CO_2, PM10, PM2.5) will be collected for each defined grid and transferred to digital format. These square grids will serve as measurement stations (Figure 4). In the final stage of the study, micro air quality index maps were created in line with the findings. These maps were prepared to visualize and evaluate the spatial distribution of micro air quality in the study area. The analyzed data revealed the quantitative and qualitative dimensions of the effects of agricultural areas on micro air quality. In particular, the contributions of agricultural activities to air quality at the micro scale and potential negative effects were examined in detail.

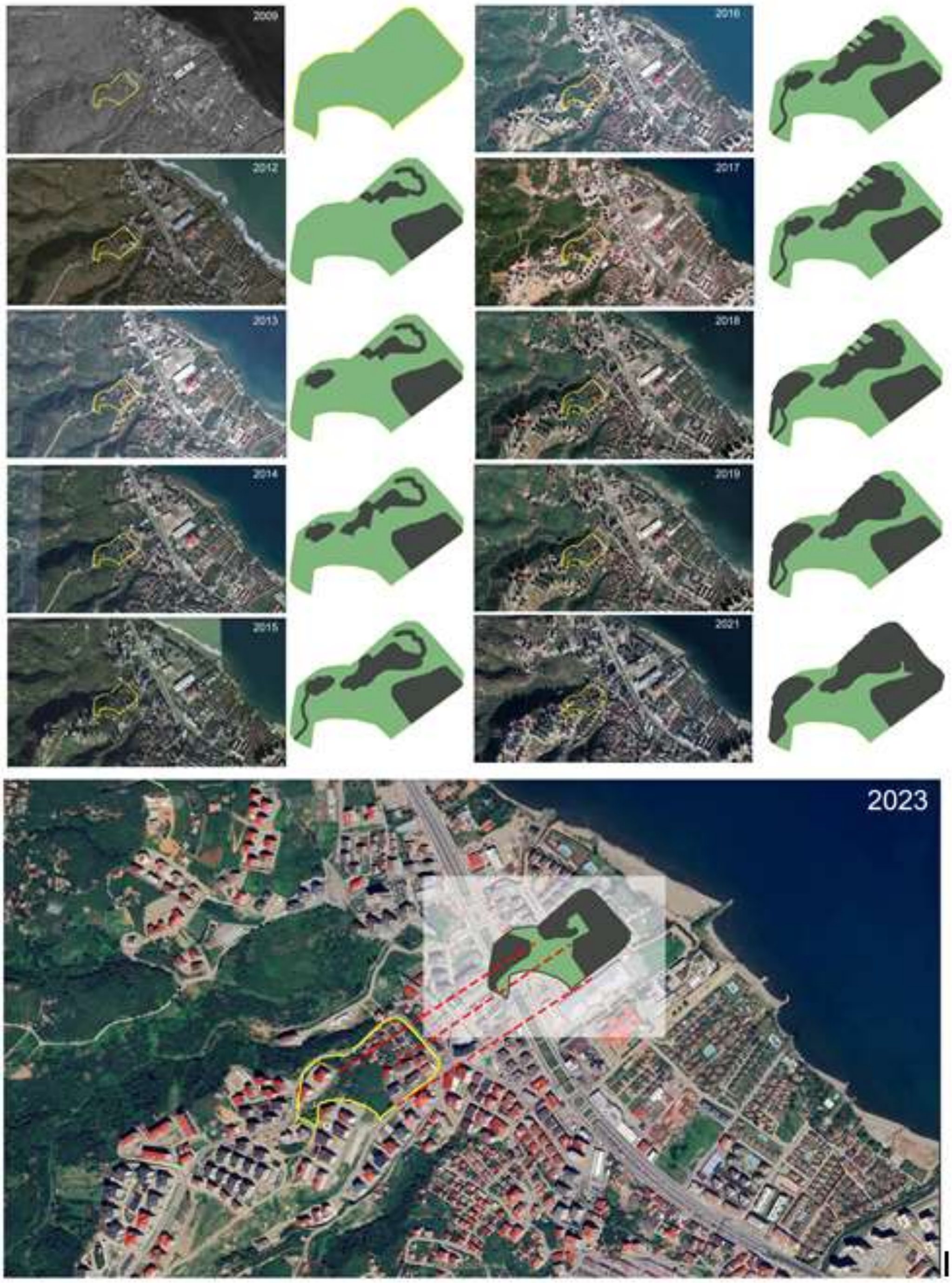

Figure 3. Changing land use of the study area between 2009-2023 (Google Map Pro)
Şekil 3. 2009-2023 yılları çalışma alanının değişen alan kullanımı (Google Map Pro)

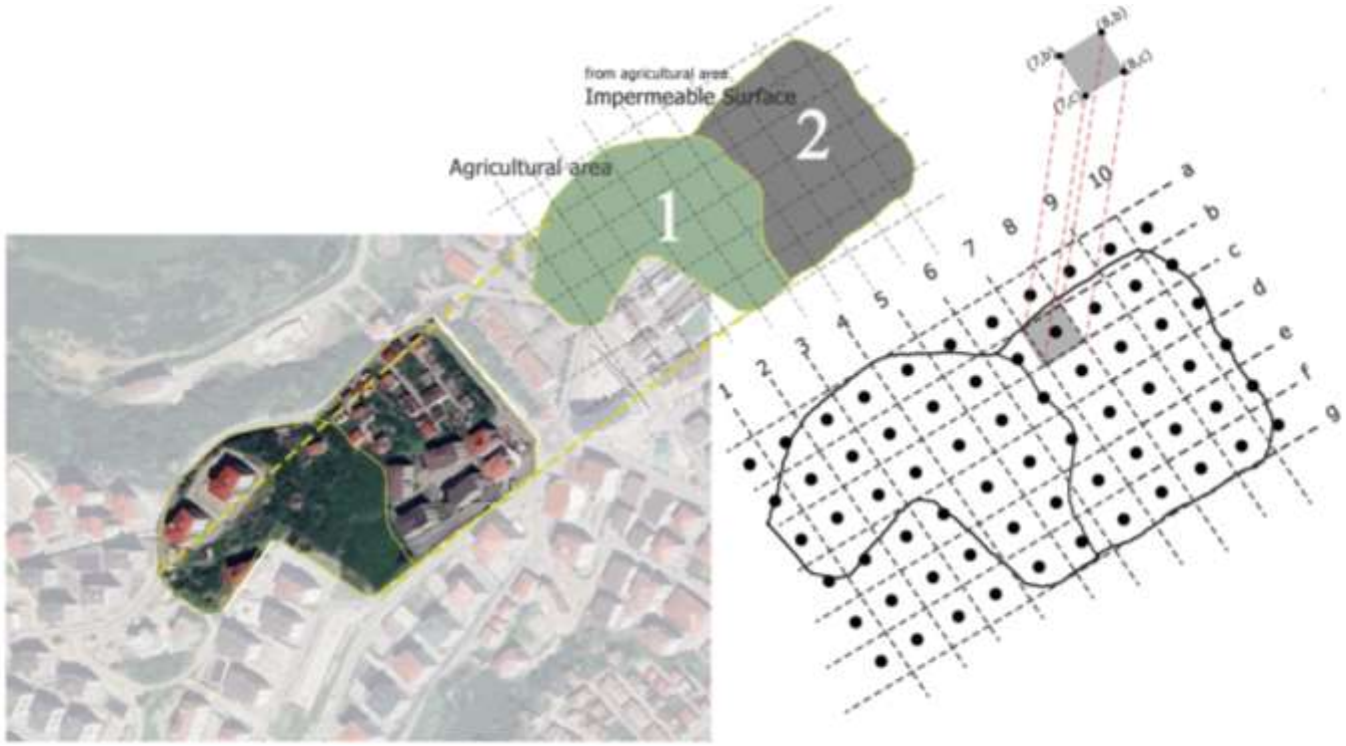

Figure 4. Grid network created for emission measurements
Şekil 4. Emisyon ölçümleri için hazırlanan ölçüm şebekesi

RESULTS

Land Use and Land Cover Changes from 2009-2023

Land use Land Cover (LULC) types were defined as Built-up and Agricultural areas. Among the selected images, those with minimum cloud ratio were filtered using the 'cloud_cover' metadata based on the ACCA (Automated Cloud Cover Assessment) algorithm developed by Irish et al. (2006) (Table 1).

Table 1. Land use Land Cover (LULC) Types and description
Çizelge 1. Arazi kullanımı ve arazi örtüsü tür ve tanımları

	LULC Types	Description	Area Recognition
1	Built-up	Living spaces, Transport infrastructure, highway, Mixed-use areas	Yellow colour
2	Agricultural	Agricultural tress	Green colour

According to LULC data, while agricultural land was 50.886 km² in 2009, this area decreased to 25.680 km² by 2023. This indicates a decrease of approximately 50%. During the same period, construction areas increased from 7.459 km² to 32.665 km² (Figure 5).. The increase in construction areas reached approximately four and a half times in 14 years. Especially since 2013, the decrease in agricultural land and the increase in construction areas have become more pronounced. While agricultural land was 42,145 km² in 2013, it decreased to 41.145 km² in 2015 and to 31.665 km² in 2018. This decreasing trend continued in 2021 and 2023 and was recorded as 29.934 km² and 25.680 km², respectively. In parallel, the built-up area, which was 16.200 km² in 2013, increased to 17.200 km² in 2015, 26.680 km² in 2018, 28.411 km² in 2021 and 32.665 km² in 2023 (Table 2).

Table 2. Land use Land Cover Changes (LULC) from 2009-2023
Çizelge 3. 2009-2023 yılları arasında arazi kullanımı ve arazi örtüsü değişimi

Year	**Argicultural area (km²)**	**Buildings (km²)**
2009	50.886	7.459
2013	42.145	16.2
2015	41.145	17.2
2018	31.665	26.68
2021	29.934	28.411
2023	25.680	32.665

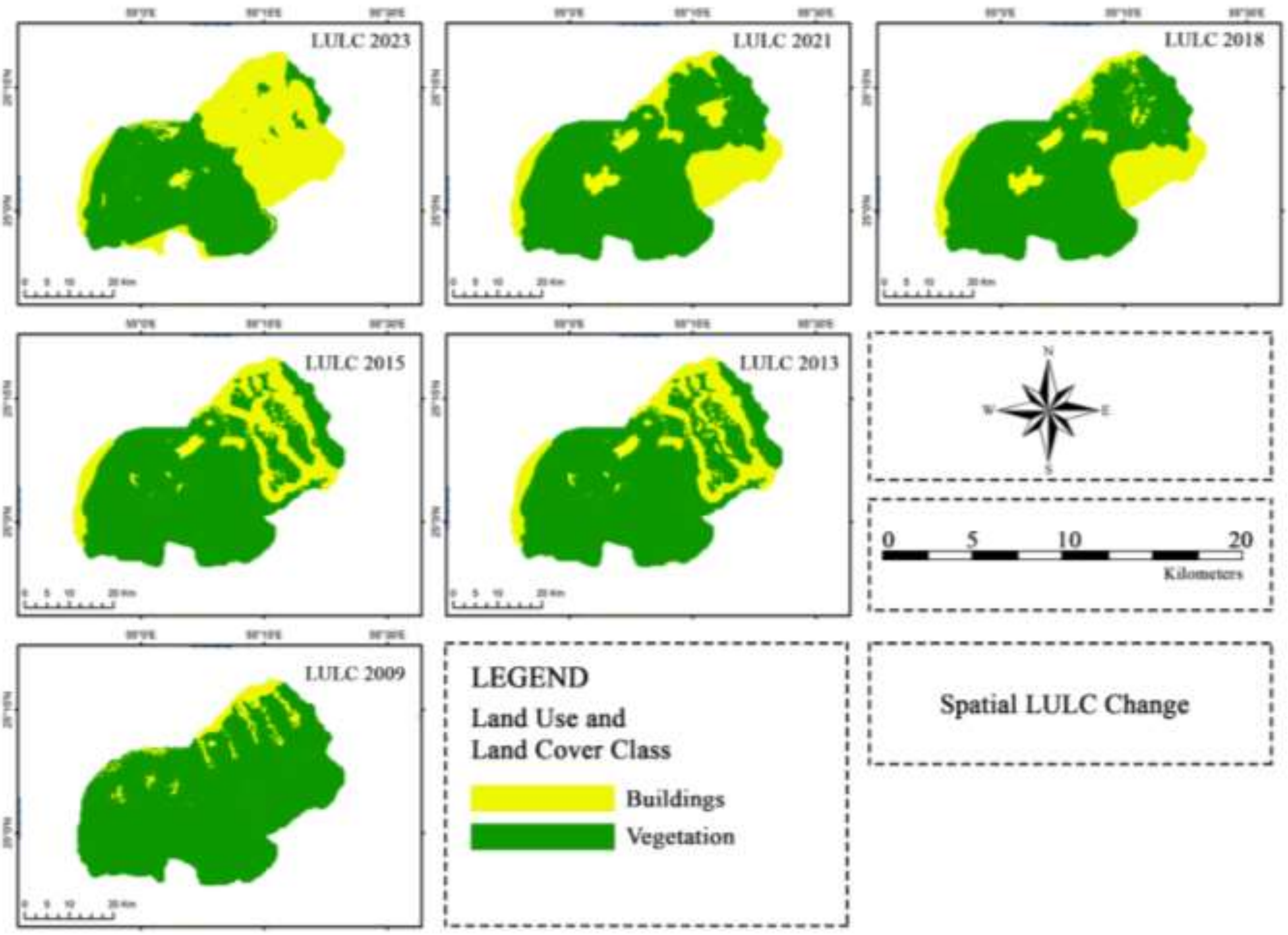

Figure 5.Land use and land cover changes maps from 2009 to 2023
Şekil 5. 2009-2023 yılları arasında arazi kullanımı ve arazi örtüsü değişim haritaları

Conducting emission measurements

Measurements will be taken 3 times during the day at different times (09.00, 15.00, 21.00). The WHO Global Air Quality Guide, published by the World Health Organization in 2021, was used to determine the measurement frequencies (WHO, 2021). Measurements were conducted throughout the entire year, from January to September 2023, thereby encompassing all four seasons. Measurements were taken 4 times a day, 120 times a month, and 1440 measurements were taken. These measurements are microscale measurements. After the measurements were made, the data were transferred to the tables and then to the computer environment. "The emission measurements were carried out using a manual hand-held device, "Makıngtec" brand equipped with an infrared sensor. In order to reveal the differences in the measurements, measurements were made from both study areas at the same time on the same day. The results obtained are given in Table 3.

When the results obtained from 25 measurement networks of the area referred to as study area 1, which is still an agricultural area, were evaluated, the following results were obtained: Carbon monoxide (CO) values varied between 1.09 μg/m³ and 2.87 μg/m³. The lowest value was measured as 1.09 μg/m³, which indicates a relatively clean air condition. However, the highest level of 2.87 μg/m³ indicates that the carbon monoxide concentration has increased significantly in some regions. This increase may be a result of emissions from human activities. Carbon dioxide (CO_2) levels varied between 251.47 μg/m³ and 429.97 μg/m³. In particular, the highest level of 429.97 μg/m³ reveals that the carbon dioxide concentration in the atmosphere has increased significantly in certain time periods and has created pressure on air quality. The average value generally provides information about the spread of this gas and the magnitude of human-induced effects. The concentrations of fine particulate matter, called $PM_{2.5}$, varied between 60.58 μg/m³ and 78.63 μg/m³. Such particles have a direct impact on human health due to their respirable size. Although the lowest value of 60.58 is relatively acceptable, concentrations reaching 78.63 μg/m³ carry potential health risks. The larger-sized particles, PM_{10}, were observed between 96.54 μg/m³ and 115.86 μg/m³. These particles generally consist of dust and other substances originating from natural sources or human activities.

Table 3. Average emission and Air Quality Index (AQI) results
Çizelge 3. Ortalama emisyon ve hava kalitesi index sonuçları

Agricultural areas

Buildings

STUDY AREA 1	Average Emission Data (µg/m³)					STUDY AREA 2	Average Emission Data (µg/m³)				
	CO	CO_2	$PM_{2.5}$	PM_{10}	AQIndex		CO	CO_2	$PM_{2.5}$	PM_{10}	AQIndex
1	1.58	351.75	60.70	100.89	105.65	1	2.84	460.88	62.59	120.61	125.85
2	2.47	251.47	61.84	101.97	108.96	2	2.98	458.96	69.85	138.96	145.96
3	2.75	341.85	60.58	102.69	111.64	3	2.17	485.63	96.47	205.96	222.54
4	1.63	348.96	65.84	105.97	119.63	4	2.58	488.74	65.67	218.96	225.96
5	1.09	307.96	68.96	110.63	120.74	5	2.14	490.63	64.18	258.96	269.96
6	1.87	416.84	65.41	109.85	111.85	6	2.68	496.41	66.85	208.99	275.85
7	2.76	413.98	70.46	112.64	109.98	7	2.48	499.63	68.96	222.95	286.96
8	2.87	403.96	72.64	115.86	117.69	8	2.58	500.17	99.63	256.96	265.95
9	2.76	418.16	65.94	108.96	119.84	9	2.48	502.63	70.48	248.96	284.96
10	2.18	406.31	75.98	102.64	108.64	10	2.68	505.47	71.64	190.63	258.64
11	1.63	407.34	75.65	96.54	100.47	11	2.98	496.78	72.64	208.65	208.96
12	1.74	412.74	71.25	98.63	99.64	12	2.94	485.96	73.95	148.96	218.96
13	1.63	403.68	70.65	99.48	101.37	13	2.69	496.34	75.95	152.63	258.64
14	2.74	348.63	70.96	100.15	105.51	14	2.74	506.48	77.85	157.96	247.96
15	2.69	341.67	71.48	101.67	108.96	15	2.63	508.94	99.85	149.96	296.47
16	2.46	369.85	72.68	105.67	111.97	16	2.67	511.74	85.65	156.95	246.91
17	2.67	349.41	73.69	107.98	109.84	17	2.65	510.48	88.69	160.98	274.96
18	1.87	307.85	75.78	105.68	112.98	18	2.98	520.59	89.61	198.51	264.95
19	1.63	317.96	74.63	102.67	105.97	19	2.47	498.96	89.17	138.96	296.47
20	1.87	409.63	78.63	108.94	112.98	20	2.63	463.47	90.46	128.98	304.85
21	1.37	408.64	72.63	96.78	99.96	21	2.48	429.75	91.65	136.87	317.96
22	1.67	418.61	71.36	99.64	101.59	22	2.71	428.94	90.64	125.95	327.64
23	2.64	429.97	74.46	100.47	103.68	23	2.43	427.61	89.64	115.68	333.48
24	2.47	427.96	71.64	101.64	104.98	24	2.48	436.17	79.68	105.85	308.96
25	2.76	407.96	69.97	103.47	110.58	25	2.09	411.75	90.85	120.25	318.64

High levels can pose a risk, especially for individuals with allergic disorders or respiratory problems. The Air Quality Index (AQIndex) varied between 99.64 and 120.74AQI. This index is an indicator that summarizes general air quality and indicates that air quality deteriorates as the values increase. The lowest value of 99.64 indicates relatively better air conditions, while reaching a level of 120.74 µg/m³ indicates a significant pollution situation. In conclusion, these data reveal that air quality exhibits significant fluctuations over time.

When the results obtained from study area 2, which is expressed as study area 2 and has transformed from agricultural areas to impermeable surfaces without any agricultural activity, were evaluated, the following results were obtained: Carbon Monoxide (CO) levels varied between 2.09 µg/m³ and 2.98 µg/m³. Although these values are in a narrower range compared to the previous data set, they show that general concentrations are on the increase. The highest value, reaching 2.98, may indicate heavy traffic or industrial areas. Carbon dioxide (CO_2) concentrations varied between 411.75 µg/m³ and 520.59 µg/m³. The lowest value is higher than the previous data, which shows that constantly high levels of carbon dioxide emissions continue. The highest level measured, as 520.59 µg/m³, clearly reveals the effects of industrial activities and fossil fuel use. $PM_{2.5}$ values varied between 62.59 µg/m³ and 99.85 µg/m³. The lowest value is close to acceptable limits, while the highest value of 99.85 µg/m³ can pose serious risks to human health. Individuals with asthma and other respiratory diseases may be more affected by this situation. PM_{10} concentrations have shown a significant change between 105.85 and 258.96. The highest level, 258.96 µg/m³, indicates serious deterioration in air quality. These particles originate from natural sources as well as human-induced activities and can cause various health problems at high concentrations. The Air Quality Index (AQIndex) has shown a large change between 125.85 and 333.48. While even the lowest value indicates a significant level of pollution, a high AQIndex such as 333.48 indicates critically poor air quality. This level can increase health risks throughout society and have more serious consequences for sensitive groups.

In Study Area 1, CO levels varied between 1.09 µg/m³ and 2.87 µg/m³, indicating that agricultural areas provide cleaner air flow and lower emission rates. Agricultural activities generally cause low levels of CO emissions. In contrast, in Study Area 2, CO levels were measured between 2.09 µg/m³ and 2.98 µg/m³, indicating higher pollution. The increase in impermeable surfaces, the density of motor vehicle traffic, and industrial activities can be considered as the main reasons for this difference. In Study Area 1, CO_2 values varied between 251.47 µg/m³ and 429.97 µg/m³, and it was observed that agricultural vegetation partially balances carbon dioxide emissions with its carbon sink capacity. However, in Study Area 2, CO_2 levels ranged from 411.75 µg/m³ to 520.59, which was due to the decrease in carbon absorption as a result of buildings and impermeable surfaces reducing vegetation cover to a great extent. In addition, energy consumption and the intensity of human activities increased the carbon dioxide accumulation in this region. In Study Area 1, $PM_{2.5}$ levels remained between 60.58 µg/m³ and 78.63 µg/m³, indicating that agricultural activities produced limited amounts of fine particulate matter. On the other hand, in Study Area 2, $PM_{2.5}$ levels ranged between 62.59 µg/m³ and 99.85 µg/m³. This increase may be due to construction activities, emissions from industries, and traffic density. The decrease in vegetation cover may have caused these particles to remain suspended in the air for longer periods. In terms of PM_{10} values, relatively low levels were observed in Study Area 1, ranging from 96.54 to 115.86. Agricultural areas limit the dispersion of dust and soil carried by wind, thus reducing the dispersion of these particles. However, PM_{10} levels were measured between 105.85 and 258.96 in Study Area 2, and this was due to the reduced capacity of impermeable surfaces to hold dust, construction activities, and increased human activities. The Air Quality Index shows the difference between the two regions most clearly. In Study Area 1, AQIndex ranged between 99.64 and 120.74, reflecting generally better air quality. Vegetation in agricultural areas was effective in absorbing air pollution. In contrast, in Study Area 2, AQIndex ranged between 125.85 and 333.48, and especially the highest value of 333.48 µg/m³ indicated critically poor air quality. This clearly demonstrates the negative effects of the conversion of agricultural lands into impermeable surfaces on air quality. Study Area 1, where agricultural activities are carried out, has lower emission levels and better air quality thanks to the air pollution-reducing effect of vegetation. In contrast, the conversion of agricultural lands into impermeable surfaces and buildings in Study Area 2 has significantly deteriorated air quality. In particular, increases in PM_{10} and AQIndex values clearly indicate the environmental impacts of emissions from construction activities and industry. These findings highlight the environmental benefits of protecting agricultural lands and implementing sustainable urbanization plans. Increasing green areas and reducing impermeable surfaces will be critical steps to improve air quality. Environmental management policies for Study Area 2 need to be rapidly put into effect.

When the average values of the results are examined, in the study area where agricultural activities are still ongoing, the average CO value was determined as 2.152 µg/m³, the CO_2 value as 376.92 µg/m³, the $PM_{2.5}$ value as 70.55 µg/m³, PM_{10} value as 104.06 µg/m³, and AQI value as 109.004. In the 2nd study area, which was converted from an agricultural area to residential and impermeable surfaces, the CO value was determined as 2.6 µg/m³, the CO_2 value as 480.92 µg/m³, $PM_{2.5}$ value as 80.9 µg/m³, PM_{10} value as 171.16 µg/m³, and AQI value as 263.53 (Figure 6).

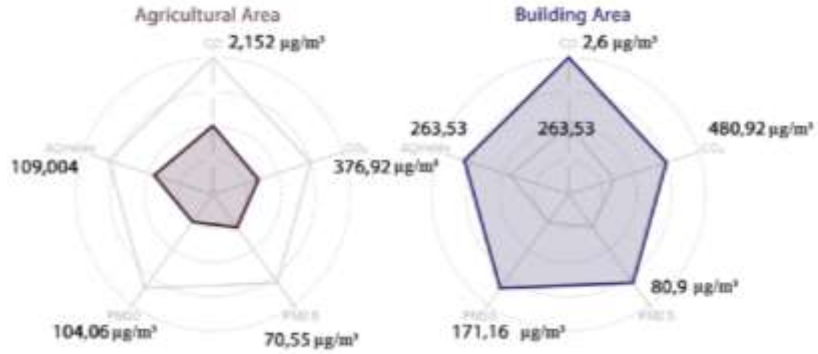

Figure 6. Radar graphic distribution of emission results
Şekil 6. Emisyon ölçüm sonuçlarının radar grafik dağılımı

Creation of Micro Air Quality Index (m-AQI) Maps

When m-AQI maps are examined according to seasons, air quality is generally better in summer months. An intense green color is dominant in agricultural areas, indicating that air quality is high. Although red tones are still seen in some areas in the built-up area, this period is relatively better than other months. In autumn and winter, it is observed that air quality deteriorates again in built-up areas. Red colors are especially noticeable in the 11th and 12th maps. In the agricultural area, green colors continue to dominate, indicating that air quality is maintained in agricultural areas. In spring and summer, a general improvement is observed in air quality. Green colors are more dominant in agricultural areas. However, there are still orange-red areas in built-up areas, indicating that the effects of construction continue in these areas. In winter, especially in built-up areas, the intensity of red color is higher, and it is observed that air quality deteriorates during this period. This can be associated with the use of fuel for heating and low air mobility. In agricultural areas, air quality is relatively better (Figure 7).

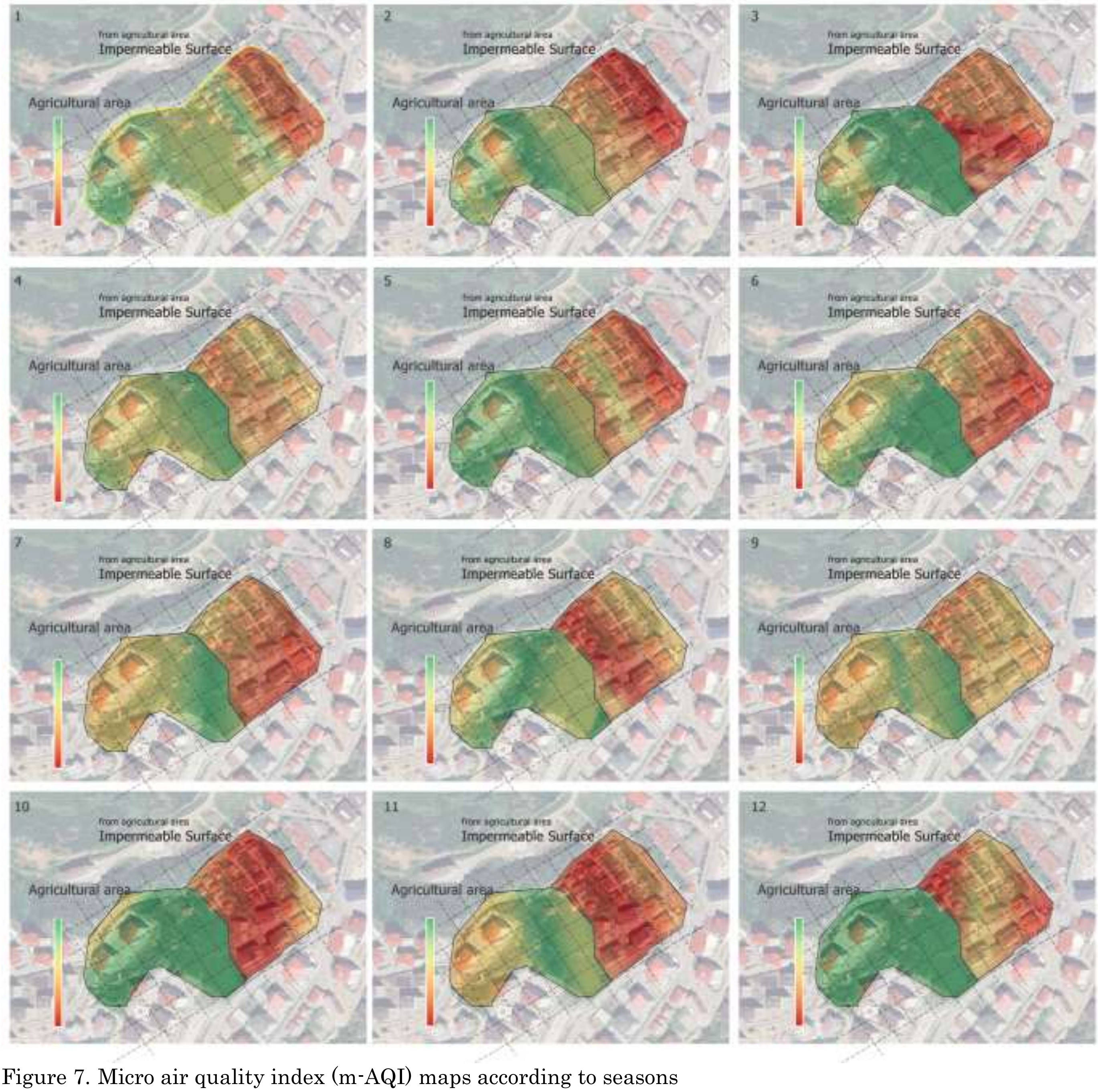

Figure 7. Micro air quality index (m-AQI) maps according to seasons
Şekil 7. Mevsimlere göre mikto hava kalitesi index haritaları

CONCLUSION and RECOMMEDATION

Today, the rapid increase in urbanization and the accompanying changes in land use pose significant challenges to environmental sustainability. In particular, the transformation of agricultural lands into residential and industrial areas adversely affects both ecological balance and air quality. In this context, the protection of agricultural areas and the investigation of their impact on the urban environment are of great importance for sustainable urban planning. In line with this objective and problem definition, the findings of the study have been determined.

This study was carried out on two different areas where agricultural activities continue and are completely covered with impermeable surfaces in order to evaluate the effects of protecting agricultural areas on micro air quality. The measurements reveal the air pollution-reducing effects of agricultural areas and their critical importance for sustainable urbanization. The results obtained within the scope of this study are as follows;

Carbon monoxide (CO) is generally known as a pollutant originating from motor vehicles and the combustion of fossil fuels. In this study, it was observed that CO levels varied between 1.09 µg/m³ and 2.87 µg/m³ in Study Area 1, where agricultural activities were carried out. These values, being at relatively low levels, indicated that agricultural areas supported the flow of clean air and reduced emission rates. In contrast, CO concentrations were measured between 2.09 µg/m³ and 2.98 µg/m³ in Study Area 2. This increase was due to the increase in motor vehicle traffic and human activities caused by impermeable surfaces.

CO_2 is one of the most prevalent greenhouse gases in the atmosphere and is generally associated with energy consumption and industrial emissions. In Study Area 1, CO_2 levels ranged from 251.47 µg/m³ to 429.97 µg/m³, indicating that agricultural vegetation partially offsets atmospheric CO_2 levels through its carbon sink capacity. However, in Study Area 2, these values were measured between 411.75 µg/m³ and 520.59 µg/m³, indicating that carbon absorption decreased due to the absence of vegetation. This indicates that energy consumption and fossil fuel use are also effective due to the increase in impermeable surfaces.

$PM_{2.5}$ particles are respirable pollutants that have a direct effect on human health. In Study Area 1, where agricultural activities continue, $PM_{2.5}$ values ranged between 60.58 µg/m³ and 78.63 µg/m³. These levels generally remained within acceptable limits and revealed that agricultural areas produce low amounts of fine particulate matter. However, in Study Area 2, $PM_{2.5}$ values ranged between 62.59 µg/m³ and 99.85 µg/m³. Construction activities, industrial emissions, and reduced vegetation cover have caused $PM_{2.5}$ concentrations to increase in this region.

PM_{10} particles generally include dust, pollen, and other large particles originating from human activities. PM_{10} values were observed between 96.54 µg/m³ and 115.86 µg/m³ in Study Area 1, while these values were measured between 105.85 µg/m³ and 258.96 µg/m³ in Study Area 2. It was observed that agricultural areas limit the dust and soil carried by wind and reduce the spread of these particles. On the other hand, PM_{10} levels increased significantly with the increase in impermeable surfaces.

The Air Quality Index is considered a summary of the overall air quality. In Study Area 1, AQIndex varied between 99.64 and 120.74, reflecting generally better air quality. In contrast, in Study Area 2, AQIndex was measured between 125.85 and 333.48, with the highest value indicating critically poor air quality.

This study reveals that agricultural areas have a significant impact on micro air quality. The presence of vegetation in agricultural areas increases carbon absorption, reduces particulate matter concentrations, and improves overall air quality. On the other hand, the conversion of agricultural areas to impermeable surfaces causes significant increases in CO_2, $PM_{2.5}$ and PM_{10} concentrations in particular. In light of these results, recommendations for future studies are as follows;

- Design professions, especially architects and landscape architects, should be in positions to produce strategies on these issues (Liang and Gong, 2020).
- Agricultural lands can be planned to form an ecological network, an ecological corridor, connected to other green areas within the city (Wang et al., 2021).
- In order to encourage the protection of agricultural lands, these areas can be redesigned as urban agricultural parks that bring together agricultural production, education, and recreation activities. In this way, agricultural lands can be protected both functionally and sustainably (Guneroglu and Bekar, 2016).
- Landscape architects should plan agricultural areas within the city with a protection-first approach and prepare long-term strategic landscape plans that will prevent these areas from being opened to construction (Aneja et al., 2009).
- Agricultural lands within the city should be determined and then grouped according to their characteristics, locations, and cultivable plant taxa (Guneroglu and Bekar, 2016).
- As in many other countries, policies aimed at protecting agricultural areas within the city should be increased (Aneja et al., 2009; Duan et al., 2021).
- Public awareness of these issues, especially micro air quality and other environmental benefits of agricultural lands within the city, should be increased (Zhang et al., 2022).
- By designing green belts or buffer zones surrounding agricultural lands, these areas can be protected from urbanization pressure (Aneja et al., 2009).

In urban planning, preserving agricultural areas and increasing green areas are critical steps to improving air quality. In addition, reducing impermeable surfaces and minimizing energy consumption stand out as effective strategies to limit emissions. The study highlights the critical importance of urban planning policies, particularly the impact of preserving agricultural lands and developing sustainable urbanization strategies. The loss of agricultural land due to urban expansion not only leads to environmental issues but also brings about various other challenges. Therefore, urban planning should take these issues into account and implement measures to address them. Regulations and strategies must be developed to protect agricultural lands. Urban planning and urban development policies should focus on preserving agricultural areas as green spaces, enhancing urban sustainability, and recognizing that these areas provide not only agricultural production but also ecological and social benefits. Protection of air quality and improvement of living conditions are of great importance in reducing the negative impacts of urbanisation. At this point, environmentally friendly residential areas, energy-efficient and nature-friendly buildings, and the support of modern urban planning techniques play a critical role in achieving sustainable urbanisation goals.

In conclusion, this study clearly demonstrates the positive effects of agricultural areas on micro air quality. The air pollution-reducing effect of vegetation shows that sustainable environmental management should be made a priority. Protection of agricultural areas and implementation of sustainable urbanization plans will be important steps that will provide both environmental and social benefits.

Araştırmacıların Katkı Oranı Beyan Özeti

Dr. Makbulenur ONUR has designed the study and collected the data.

Çıkar Çatışması Beyanı

None.

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