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NEW CHALLENGES FOR XXI CENTURY CITIES

Multilevel scientific approach to impacts of global warming on urban areas, energy transition, optimisation of land use and emergency scenario

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TeMA Journal was established with the primary objective of fostering and strengthening the integration between urban transformation studies and those focused on mobility governance, in all their aspects, with a view to environmental sustainability. The three issues of the 2025 volume of TeMA Journal propose articles that deal with the effects of Global warming, reduction of energy consumption, immigration flows, optimization of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters and multilevel governance approach to adaptation.

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The cover image shows a composition of two photos of the Temple of Serapis in Pozzuoli (Italy). Giuseppe Mazzeo took them in January 2009 and March 2025. At the top, the 2009 image shows the temple flooded, with the pavement not visible. In the down, the 2025 image shows the temple's pavement dry and exposed. The Temple of Serapis is one of the leading visual indicators of the bradyseism phenomenon in the Phlegraean Fields. The bradyseism phase, highlighted by comparison, started in the first years of this century, as shown by the data published by the National Institute of Geophysics and Volcanology (INGV) on the website dedicated to the phenomena (https://www.ov.ingv.it/index.php/il-bradisismo).

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The impact of transportation planning on agricultural areas and plant health: a case study of Antalya/Konyaaltı West Ring Road

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Abstract
It is stated in the literature that changes in land cover/land use may have positive or negative effects on accessibility and rural-urban distinction in the region. Similarly, increasing accessibility in an area may lead to unplanned urbanization, traffic congestion, air, and noise pollution, and a decrease in the environmental quality of life due to the impact on land use and, most importantly, the destruction of agricultural areas. In the planning of urban and rural areas, the interaction with each other and the formal separation of rural and urban areas are important, and many analyses, such as accessibility, protection of agricultural areas, building density, and population, should be carefully made in order to avoid negative impacts on each other. In the studies without such analyses, unplanned or unjustified urban areas emerge where the direction of urban development has not been determined. This study analyzes the West Ring Road in the Konyaaltı district (Antalya), where a similar situation is experienced, and the surrounding agricultural areas. It is claimed that the agricultural lands around the West Ring Road have lost their agricultural quality. With this study, we seek empirical answers to these claims. Our aim is to analyze the effects of the West Ring Road on the agricultural areas around it, in conjunction with plant health, through GIS (Geographic Information System) and Remote Sensing methods. As a result of the study, the plant health in the rural agricultural areas on the periphery of the West Ring Road was not negatively affected.

Keywords: Agricultural land; Change detection; GIS; NDVI; Ring road; Transportation-land use.

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1. Introduction

The mass migration from rural to urban areas triggered by the increasing demand for the workforce by industrialization that started in the 1950s has taken a different path over recent decades, which requires reconstruction of the relationship between urban and rural areas. In Antalya, this relationship began to intensify in recreation and tourism in the 1980s, and now it has moved to a different dimension. As Sietchiping et al. point out, increasing rural-urban relationships cause environmental problems due to limited land and excessive consumption of resources. Improving the integration and balance between urban and rural areas necessitates devising various spatial planning systems and tools (Sietchiping et al., 2014). Lefebvre et al. state that phenomena like "total urbanization" and "entire city" are replacing industrial cities day by day, referring to the process that Turkey is going through today (Lefebvre, 2003).

Economic changes and developments that accelerated urbanization also led to the development of labor-intensive industries, service sectors, and non-agricultural industries in rural-urban connections. Tao reports that Asian cities have been abandoning this dual rural-urban structure to strengthen rural and urban integration (Tao, 2007). The transformation of the countryside has brought about significant changes in the dynamics of the local economy, with agriculture being no longer the backbone of the rural economy, resulting in the rebuilding of rural populations. With the change in the rural population structure, new usage areas have emerged in the countryside, thus creating novel income and real estate sectors (Brereton et al., 2011). Urbanization not only stems from the movement from rural to urban areas but also from the need of those living in urban areas to be close to rural life. In this regard, the reason for the emergence of problems in the planning and spatial design of urban areas is the lack of understanding of the integrity of the part-whole relationship that solves urban problems and the priority given to the creation of weak urban areas that are incompatible with their surroundings and have no connection with their periphery.

One of the key components of economic growth, transportation aims to improve the capacity of individuals to access various economic and social activities, which is among the main objectives of urban transport policies (Foth et al., 2013; Zhu & Liu, 2004). Accessibility is the ability to access opportunities (services, goods, activities, facilities) from the current location using the existing transportation network. Accessibility is influenced by various factors such as transport type, demand, integrated transport, mobility, passengers' experience and knowledge, ability to pay, transport costs, management, topological interconnection of transport networks, and privatization. Accessibility is generally defined in the literature as the most basic product of the transportation network. In addition, accessibility is an important tool for measuring the impact of transportation decisions on the city (Geurs & van Wee, 2004). Accessibility directly impacts social, cultural, economic, and environmental technical factors as well as planning, land use, and transportation systems. The building supply created in a planned satellite city changes the location of activities, such as sports facilities and shopping centers in that region, which changes the demand for meeting areas. Changing land use will increase travel demand, thus requiring adequate transport infrastructure. This change has profound effects on sustainability in urban areas.

Since the 1960s, much research and work has been done to clarify the planning and interaction between transport networks and land use (Alonso, 1964; Anas, 1982; Boyce, 1980; Brandi et al., 2014; Buliung & Kanaroglou, 2006; Demirel, 2004; Hawkins & Nurul Habib, 2019; Ing et al., 2001; Lopez-Ruiz et al., 2013; Wegener & Fürst, 2004). In such studies, scholars determined that the urban-rural relationship and changes in land cover/land use could positively or negatively affect accessibility in the region. Indeed, increased accessibility in an area may lead to unplanned urbanization, traffic congestion, indistinguishable industrial and residential areas, air and noise pollution, a decrease in environmental quality of life due to the impact on land use, and, most importantly, the destruction of agricultural areas. In planning urban and rural areas, factors like urban-rural interaction and formal separation of such areas are vital. Therefore, various analyses should be carried out on accessibility, protection of agricultural areas, building density, and population so that they exert no negative effects on each other. In regions without such studies, we often observe unplanned urban areas created without any justification or direction of urban development.

In measuring the impact of urban areas on rural areas, researchers have been using various methods across agricultural areas, such as on-site crop yield assessment, product diversity, plant health measurement by remote sensing technique, and soil moisture assessment. Recently, however, the high costs of field studies into the effects of urban areas on their periphery and problems experienced in measuring plant health and crop yield on site have caused the adoption of new research approaches that employ remote sensing technologies. However, it is stated that more empirical studies are still needed on the effects of resource uses on land cover change (Futemma & Brondízio, 2003). In order to determine the impact of infrastructure projects on the environment, it is important to determine changes in plant health along with changes in land cover. Thus, it will be predictable what impact infrastructure projects to be developed in a similar area will have on the environment.

The West Ring Road, planned on agricultural lands in the North of Konyaaltı district (in Antalya) in 2014, is an infrastructure project that has been discussed for many years and has brought about concerns about the above-mentioned transportation planning-environment interaction. This area is approximately 282.40 ha in size, including the agricultural lands around it. Authorized administrations claim that the agricultural area around this area lost its quality after the West Ring Road was opened, and they want to plan this area as a new settlement. Based on this, in this study, the effects of the West Ring Road on agricultural areas are analyzed with different algorithms using remote sensing and GIS methods. Scientific and quantitative answers are sought to the authorized administrations' claims that the transportation axis hurts agricultural areas. Thus, it has been revealed that the effects of the proposed transportation axis located on the urban periphery on the unbuilt environment can be evaluated.

2. Literature review

In 1989, Singh defined the simplest change detection method as subtracting the pixel values of two images registered at different times (Singh, 1989). Indices or band ratios, such as vegetation, are usually derived before any image differentiation. Thanks to the rapid advances in remote sensing technologies, which can yield various satellite data, we can rapidly and effectively detect the interaction between urban areas and agricultural lands. Thus, the number of studies conducted to determine the impacts of urban areas on farming lands through different indices and applications created with satellite images is increasing daily.

Futemma and Brondízio compared land cover-land use change (LULCC) in agricultural and forest lands before, during, and after constructing the Inter-Oceanic Highway (Futemma & Brondízio, 2003). As a result of this study, which used the maximum likelihood change detection algorithm, it was determined that there was a 2% decrease in forest areas in 11 years. Similarly, Michaelsen et al. also evaluated the impact of the highway on natural resources by comparing the 15-year LULCC change in Peru (Chávez Michaelsen et al., 2013). Arima et al. modeled the impact of road construction on forests (Arima et al., 2005). Samal and Gedam, in their study analyzing the change in land cover, associate the change in residential areas with the decrease in agricultural lands (Samal & Gedam, 2015). In their study on the coasts of India, Kaliraj et al. found that the increase in the built environment over 10 years poses a serious threat to coastal resources (Kaliraj et al., 2017). Alphan found that 30% of the changes in the built environment in 16 years affected agricultural lands in Adana, Turkey (Alphan, 2003). In the study of Wang et al., in which they examined the destruction of land along the China-Mongolia Railway, they found that the degree of land degradation increased due to reasons such as infrastructure construction and urbanization (Wang et al., 2019).

Landsat satellite images are frequently used in change detection studies in the literature. Although Landsat, one of the traditional Earth observation satellites, is effective in larger areas due to its resolution, it can achieve spatially satisfactory results with the help of new generation sensors working with different satellites. Other factors in choosing Landsat satellite images are that the images have bands with different properties, are freely available, are radiometrically corrected, and have been successfully used in research for many years, leading to successful results. In addition, Landsat images are used extensively in measurement and change detection analyses of plant health and yield in agricultural areas.

2.1 Our motivation and urban development in surrounding agricultural areas

The impact of urban development on agricultural areas is a multidimensional transformation process involving planning, environmental sustainability, and economic dynamics. Changes in land use, infrastructure investments, air and water pollution, microclimate alterations, and rising land prices are among the primary factors directly or indirectly affecting rural areas. Uncontrolled urban expansion threatens long-term spatial sustainability by leading to the loss of agricultural land and the depletion of environmental resources (Samat et al., 2020).

The primary motivation for this study is the need for a scientific assessment of the risks posed by administrative decisions allowing urbanization of agricultural land surrounding the West Ring Road in Konyaaltı. The decision by the Antalya Soil Conservation Board on October 3, 2012, to allow non-agricultural use of the area, followed by the approval of a 1/25,000-scale master zoning plan by the Antalya Metropolitan Municipality Council on September 13, 2019, has subjected this land to significant urbanization pressures. Although local communities and civil society organizations have legally intervened, temporarily halting the construction process, large-scale real estate developers continue to exert pressure on local authorities.

In this context, our study evaluates the spatial and environmental consequences of converting agricultural land for urban use, emphasizing the necessity of sustainable planning. Remote sensing techniques and Geographic Information Systems (GIS) should be utilized to assess the impacts on agricultural areas, ensuring the implementation of sustainable land-use policies. In cases where urban expansion is not effectively managed, agricultural lands have been observed to face rapid urbanization pressures (Esopi, 2018). This study provides a scientific basis for managing this process in accordance with spatial planning principles.

3. Materials and methods

3.1 Case study area

A coastal city in the south of Turkey, Antalya ranks among the provinces with the highest population growth rate between 2013 and 2022. Our study area is located within the borders of Konyaaltı, which is the 5th most populous district of Antalya, with a population of about 200,000 according to 2021 data. Its continuously swelling population demands new settlement and housing areas.

The Konyaaltı West Ring Road, examined within the scope of the study, is a part of the D-400 Highway, the most important of the six main highway axes connecting the city to the country's transportation network. D-400 Highway starts from the Datça District of Muğla and ends at the Esendere border gate of the Yüksekova District of Hakkari. The roles and functions of this ring road in the urban and regional transport link can be listed as follows:

- Conveying traffic, mostly heavy vehicles, from Central Anatolia to the port of Antalya;
- Providing vehicle traffic from Anatolia and Istanbul to tourism-intensive regions (such as Göynük, Kemer, Çamyuva, Çıralı, and Adrasan);
- Allowing swift delivery of agricultural produce from intensive farming regions (such as Kumluca, Finike, Kemer, Turunçova) to Central Anatolia and big cities such as Ankara and Istanbul;
- Establishing a transportation link to various areas within the city.

Our study examined the 1900-meter-long section of the West Ring Road, surrounded by agricultural lands in the east and west. These lands cover an area of approximately 282.40 hectares, and the local authorities intend to convert this plot into a new residential area with the hypothesis that agricultural productivity has declined in the region since the West Ring Road opened. We also tested the validity of this hypothesis.

The planning and construction of the Western Ring Road is not merely a decision aimed at improving transportation infrastructure but is also closely linked to the municipality's strategy to offset expropriation costs. The expropriation of land for the road has created a significant financial burden for the municipality; thus, it was decided to open the surrounding areas for urban development to cover these costs. As part of this strategy, landowners affected by the expropriation were allocated newly created parcels in the rezoned areas, allowing the municipality to mitigate its financial liabilities.

However, this process was not limited to the immediate area occupied by the road, as the municipality decided to open a much larger area for development. This decision has directly led to the urbanization of agricultural lands, threatening environmental sustainability and accelerating urban sprawl. Moreover, since natural or artificial boundaries were not considered when determining the zoning limits, not only the areas adjacent to the road but also surrounding agricultural lands have been indirectly subjected to development pressure. In planning processes, it is crucial to establish clear natural or artificial boundaries for zoning decisions; otherwise, these boundaries may not remain permanent and could lead to further development demands (Suri, 2018). Natural and artificial thresholds play a critical role in maintaining ecological balance and preventing uncontrolled urban expansion in spatial planning.

The rezoning of this area not only expands transportation infrastructure but also represents a speculative economic approach that deviates from fundamental spatial planning principles, posing a significant risk to sustainable land management. In the long term, this process contributes to the decline of agricultural production areas, depletion of environmental resources, and disruption of ecological balance (Esopi, 2018).

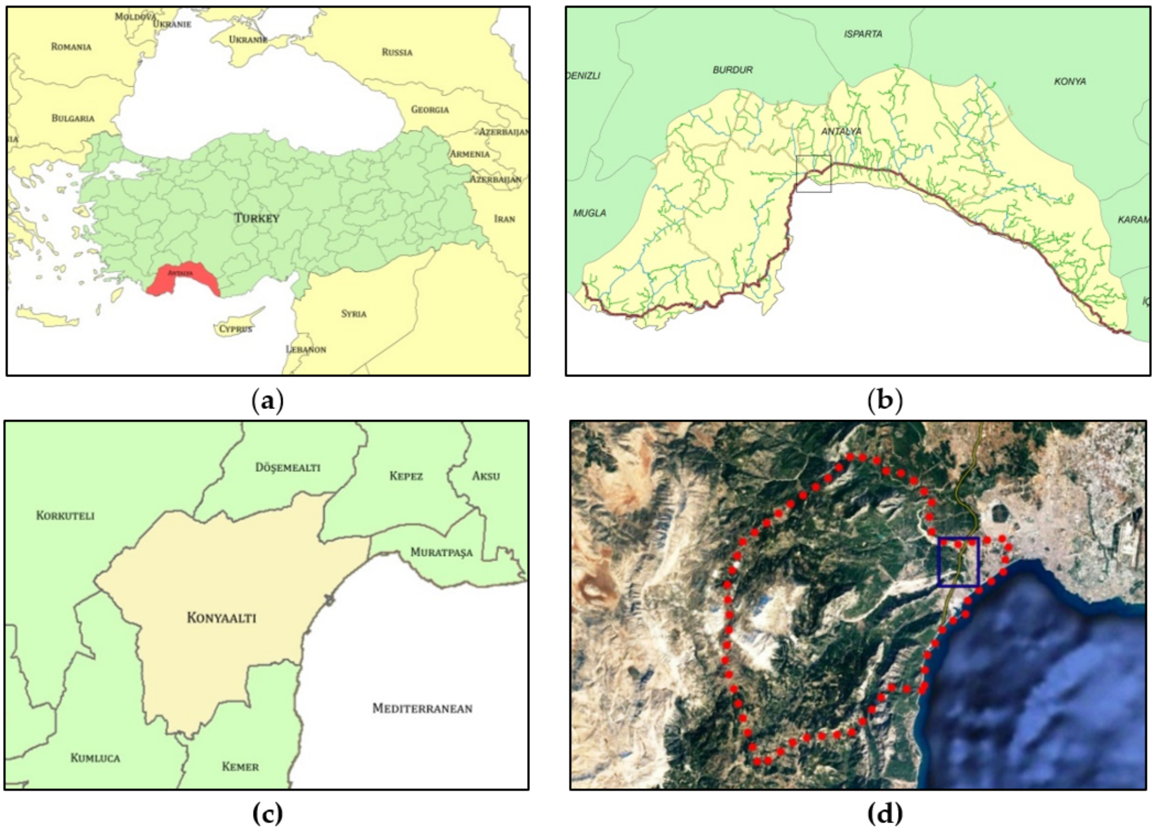

Fig.1 Location of the study area (a) Antalya province in Turkey (b) Konyaaltı district in Antalya province (c) Konyaaltı and surrounding districts (d) Satellite image of Konyaaltı district

The study area, which is approximately 282.40 hectares, is located between 286,000 – 288,000 x and 4,083,000 – 4,086,000 y coordinates according to the UTM ED50 projection system. NATO pipeline forms its western border, and Çandır Stream the southern border, while Karaman Stream draws its eastern and northern borders (Fig.s 2 and 3).

In this study, Geographic Information Systems (GIS) and Remote Sensing methods were employed to analyze land cover changes and plant health in agricultural areas surrounding the Western Ring Road. These techniques were chosen for their ability to process large-scale spatial data, detect temporal variations, and provide objective, replicable results in land-use transformation studies.

The Normalized Difference Vegetation Index (NDVI) was applied to assess plant health, while GIS-based spatial analysis integrated satellite imagery and topographical data to quantify land-use changes. This approach enables identifying spatial patterns and evaluating the impact of urban expansion on agricultural lands.

By combining remote sensing and GIS-based analysis, this study provides empirical evidence on the effects of infrastructure projects on agricultural areas, ensuring a scientific basis for sustainable land-use planning.

The lands around the study area are classified into three groups: "urban residential areas," "non-agricultural lands," which consist of riverbeds, and "absolute and cultivated agricultural lands." The interaction of non-agricultural lands and urban residential areas with the study area is the protected area effect created by the natural borders. Karaman Stream surrounds the area as an arc from the east and northeast of the agricultural areas, forming a border with the urban areas in the east. Similarly, Çandır Stream surrounds the area from the south and forms a border with the Muhasara urban settlement area. The natural border formed by these two streams prevented the urban pressure on the agricultural area in question. To the west of the study area, the Çakırlar region is a similar area that still maintains its agricultural character with its citrus groves and rural life. From the Karaman stream, agricultural lands continue uninterruptedly for about 5 kilometers in the west direction (Fig.2).

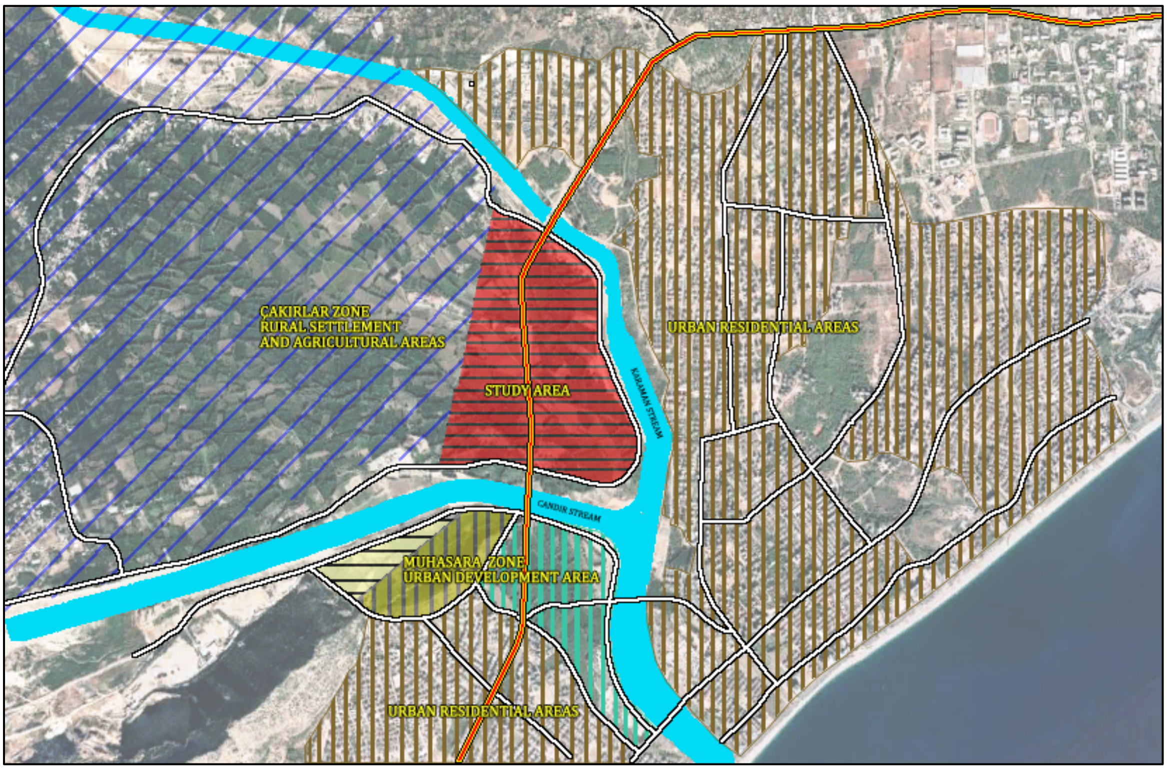

Fig.2 Location of the study area on topographic map and satellite image

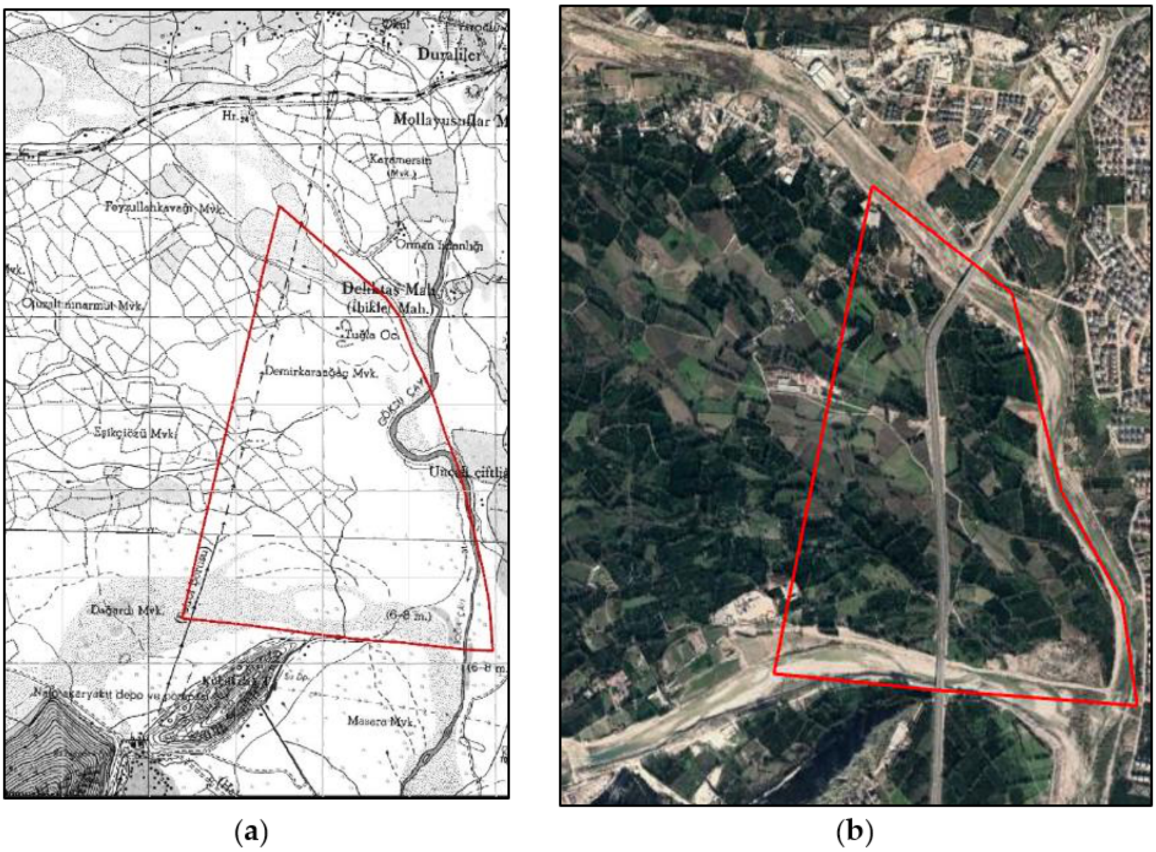

Fig.3 (a) Location of the study area on the topographic map (b) Location of the study area in the satellite image

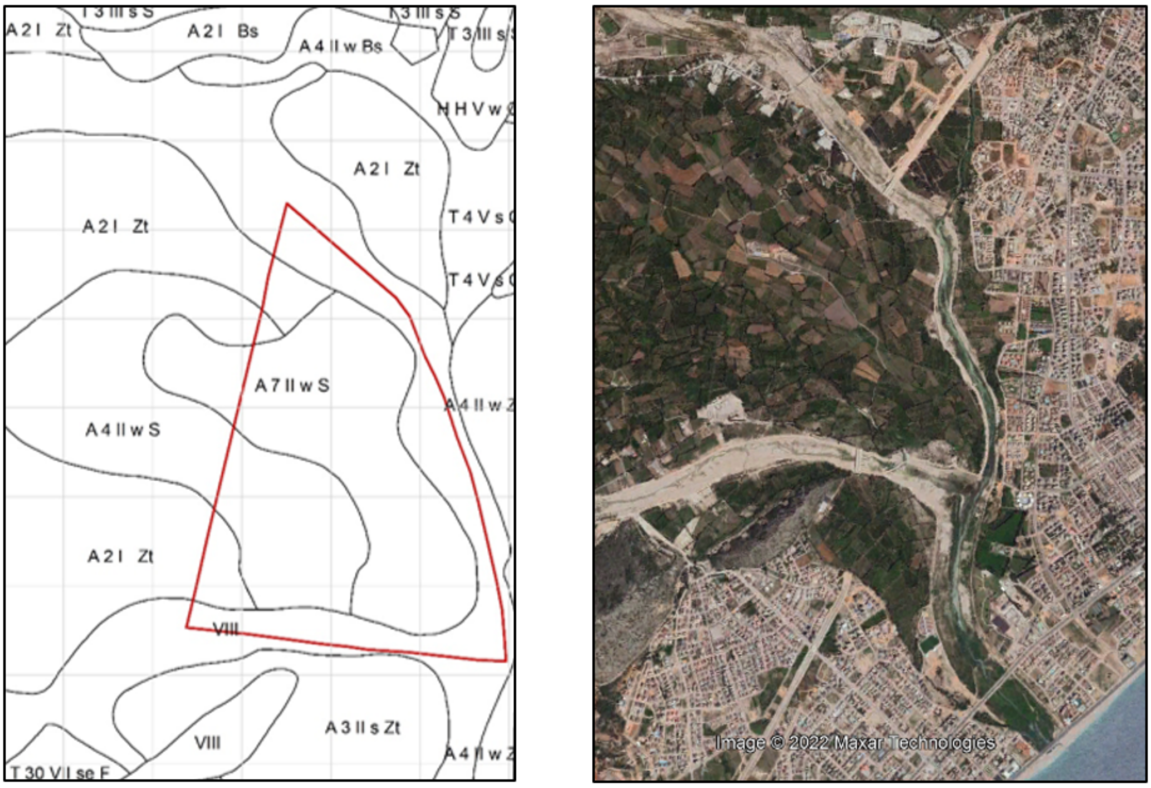

Fig.4 (a) Location of the study area on the soil map (Antalya Province Land Presence) (b) Satellite image of the area before the construction of the West Ring Road

The study area is a part of the agricultural basin. In the north of the area, there are agricultural lands in the villages of Bahtılı and Çakırlar, and they constitute agricultural areas as a whole with their soil, land use, and vegetation characteristics. The region located east of Karaman Stream and south of Çandır Stream maintains its current status as a planned urban area, as seen in Fig.4. The western part of the area is surrounded by cultivated agricultural lands, with citrus and pomegranate groves. The examinations performed in the area determined that the area consisted of irrigable lands with a slight slope (0-2%), deep (90 cm+) soils, no drainage problems, and with these features, it falls into the categories of Absolute Agricultural Lands and Cultivated Agricultural Lands.

Another classification conducted in terms of the agricultural capacity of the area was the Land Capability Classification. According to the Soil Map obtained from the Antalya Province Land Size Report, there are soil units with the symbols A2I Zt, A4 II wS, and A7 II wS in the study area. These lands are located in the Alluvial Great Soil group and are classified as type I and II, according to the Land Capability Classification. According to the same classification, type VIII lands also exist, which are riverbeds of Karaman Stream and Çandır Stream, and they are classified as non-agricultural areas. Accordingly, the measurements on the map revealed that approximately 240 hectares of the study area (282.40 hectares) consisted of agricultural lands and the remaining 42.4 hectares of non-agricultural areas, as seen in Fig.4.

3.2 Datasets

In an attempt to assess the damage to plant health in the agricultural lands, we performed (Normalized Vegetation Index) and dNDVI (Difference Normalized Vegetation) analyses using GIS and Remote Sensing (ArcGIS 10.5) programs on 30-meter resolution Landsat 8 and 9 images dated 17.06.2014, 20.06.2015, 22.06.2016, 25.06.2017, 12.06.2018, 15.06.2019, 03.07.2020, 06.07.2021, and 15.06.2022. The results of plant presence and plant health analyses were compared to show the areas with concentrated plant presence and determine the water presence.

Landsat satellite data are among the important datasets to detect the effects of urban areas. Landsat 8 and 9 satellites, which have eleven (11) spectral bands, have a resolution of 15 m in the eighth band and 100 m in the 10th and 11th thermal bands. The other bands have a resolution of 30 meters, so the studies in the literature frequently use these data to determine the field changes and their effects. The band, wavelength, and resolution properties of satellite images are given in Table 1.

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 – Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 6 - SWIR 1	1.57-1.65	30
Band 7 - SWIR 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19	100
Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51	100

Tab.1 Landsat 8 and 9 Satellite Image Features (https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites)

3.3 Method

Remote sensing techniques are a contemporary method widely used in various fields, including identifying the spatiotemporal changes in land use (Dahanayake et al., 2024; Partheepan et al., 2023), determining suitable areas for urban development (Poudel et al., 2023), characterizing open spaces (Caprari & Malavolta, 2024), and analyzing the relationship between transportation and land use (Khatua et al., 2024).

Bands of satellite images and some remote sensing algorithms (NDVI, dNDVI) were evaluated together. According to the flowchart in Fig.5, the study consists of four basic stages: data collection, pre-processing, calculation of agricultural areas and vegetation affected by urban areas with different algorithms, and comparative evaluation.

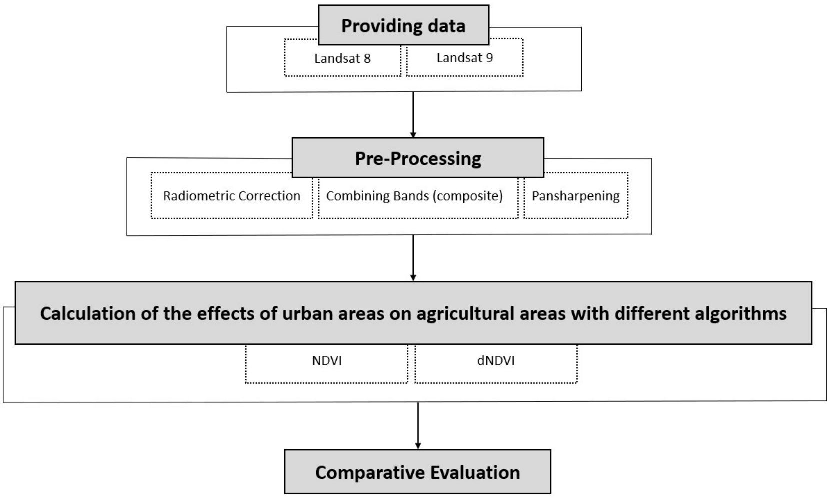

Fig.5 Flowchart

NDVI index is one of the remote sensing methods frequently used by research in the literature into the impacts of urban areas on farming lands to detect changes in damaged vegetation or living vegetation. While plants in the vegetation cover carry out photosynthesis by using the chlorophyll in their leaves, they utilize the electromagnetic energy coming from the sun in the range of 0.63μm – 0.69μm and corresponding to red light during the photosynthesis phase. Thus, it is expected that a satellite image measuring the reflection of red light will have low numerical values in areas with dense vegetation (Kandemir, 2010).

Near-infrared wavelength (0.68–0.78 μm), red wavelength (0.61–0.68 μm), NDVI indicates vegetation index value (Tucker, 1979). The NDVI index is defined within a range from -1 to +1, and in areas with dense vegetation, NDVI index values are close to NDVI + 1, while in sparse vegetation or bare surfaces, it is close to 0, and NDVI index values for water, snow, and clouds are close to -1 (Hatfield et al., 1985). dNDVI analysis is generally used in the literature to detect burned areas after forest fires. It is one of the algorithms developed in the discipline of remote sensing as one of the important analyses for the detection of changes in green areas (Afira & Wijayanto, 2022; Huang et al., 2016; Teodoro & Amaral, 2019).

$$NDVI = (NIR - RED)/(NIR + RED)$$

$$\text{for LANDSAT 8; } NDVI = (BAND5 - BAND4)/(BAND5 + BAND4) \quad (1)$$

$$dNDVI = NDVI(pre - road) - NDVI\ (post - road)$$

Colored infrared formed by band combinations is also called near-infrared (NIR) composite, with near-infrared (Band 5), red (Band 4), and green (Band 3) being used. Because chlorophyll reflects near-infrared light, this band composition analyzes vegetation presence. In particular, red-colored areas have better vegetation health.

Dark areas appear as those where water is present, while urban areas appear white. The presence of vegetation is revealed through colored infrared.

4. Results

The ring road construction in the study area started in October 2014. A cloudless satellite image of June 2014 was used to view the road construction. In order to visualize the after-road construction, eight cloudless satellite images for June 2015-2022 were obtained from Landsat 8 and Landsat 9 satellites. Calculations were made and mapped for the boundaries of the study area using NDVI (Normalized Vegetation Index) and dNDVI (Difference Normalized Vegetation Index) algorithms in a total of 9 satellite images. The beginning (2014) and end (2022) satellite images showing before and after road construction are shown in Fig.6.

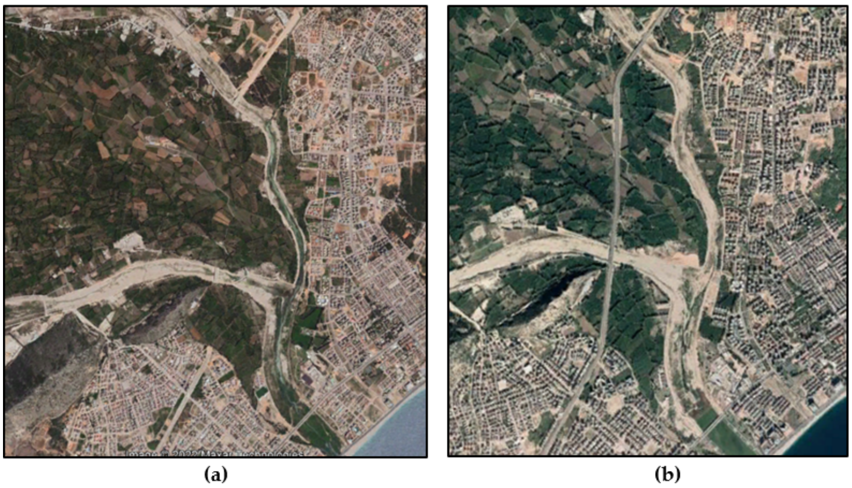

Fig.6 (a) Pre-Road Landsat 8 Satellite Image (2014) (b) Post-Road Landsat 9 Satellite Image (2022)

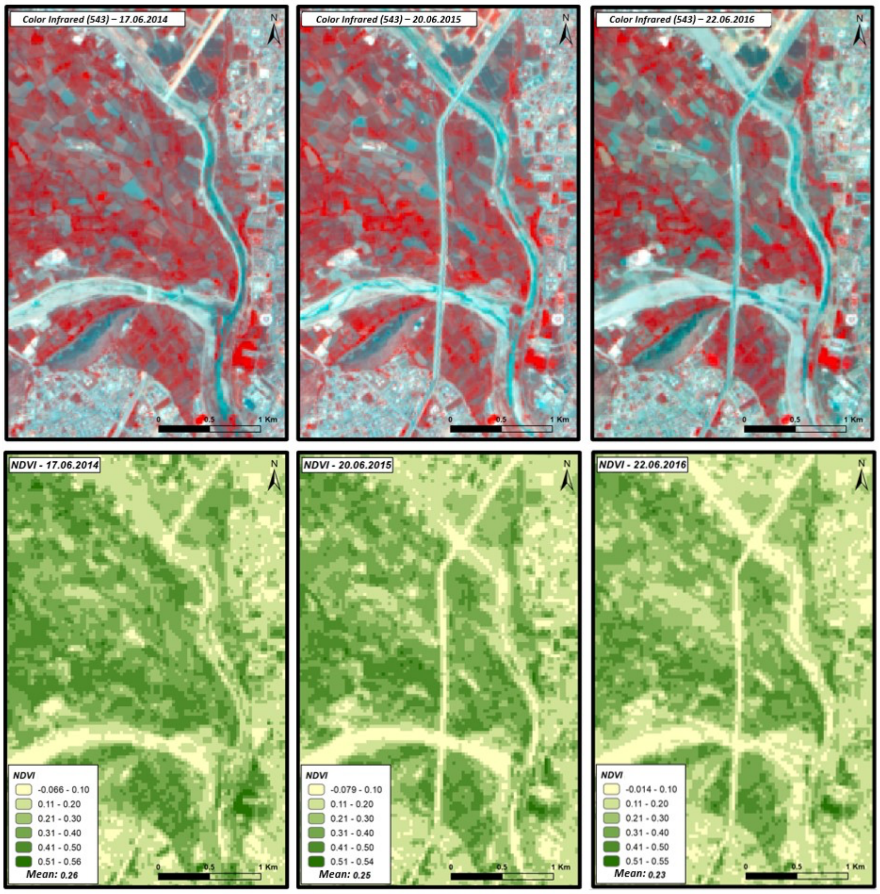

Fig.7 Color infrared satellite images and NDVI values for the years 2014 (Pre-Road)-2015-2016 (Post-Road)

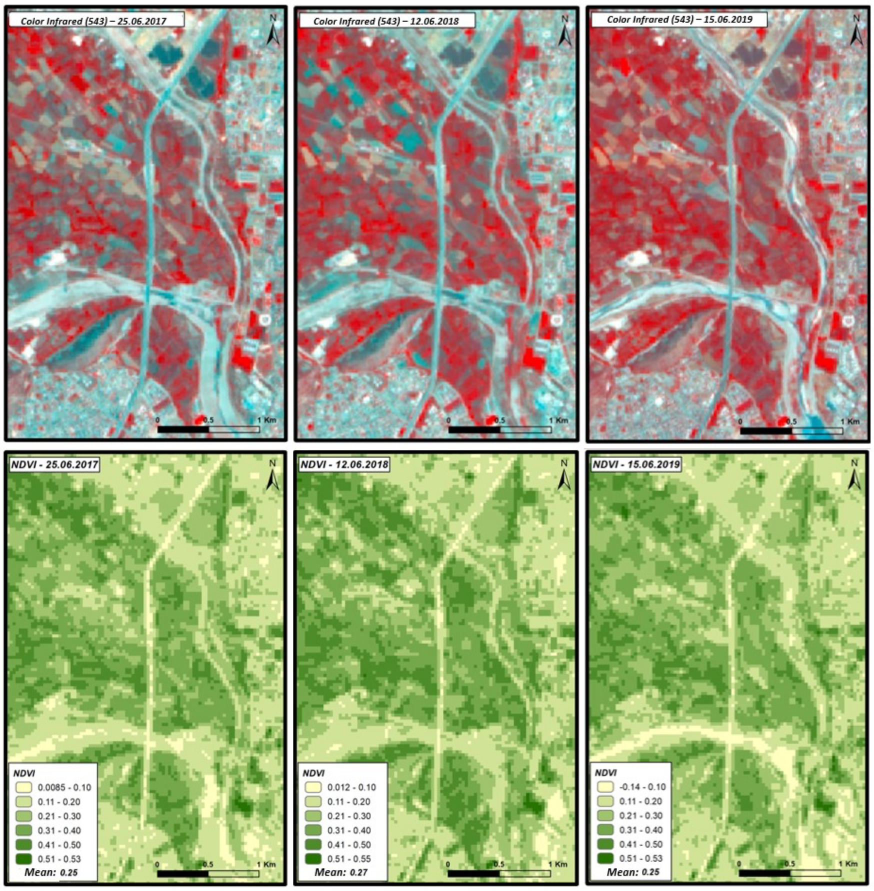

Fig.8 Color infrared satellite images and NDVI values for the years 2017-2018-2019 (Post-Road)

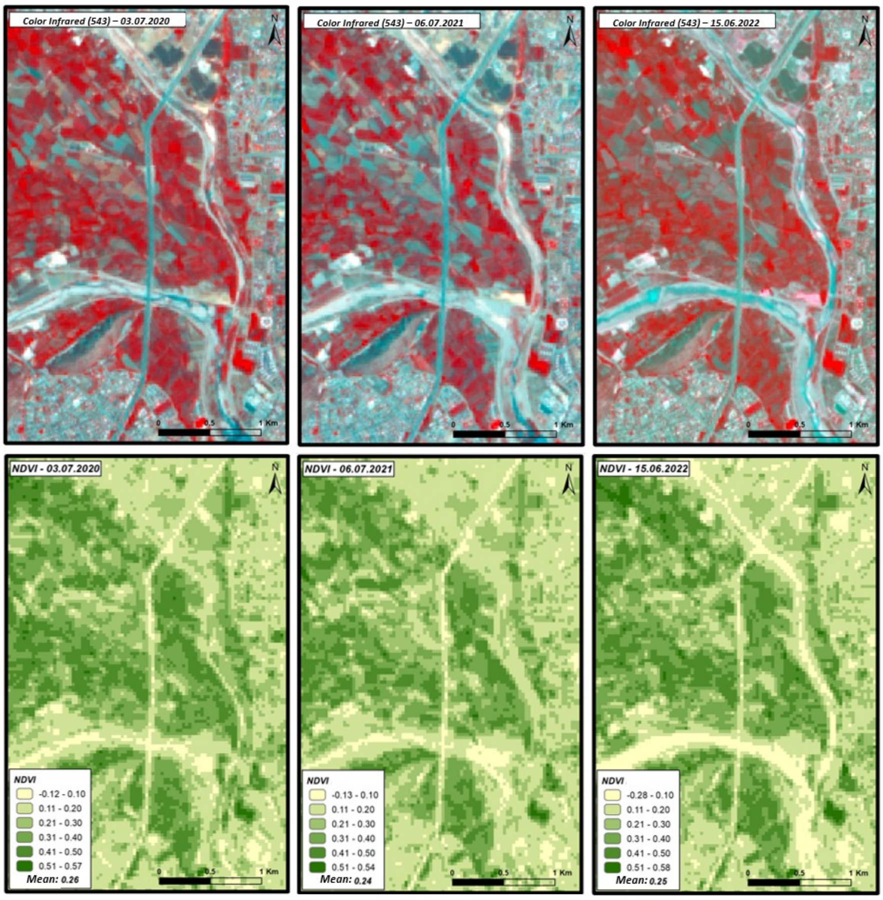

Fig.9 Color infrared satellite images and NDVI values for the years 2020-2021-2022 (Post-Road)

In statistical analyses, we compared plant health NDVI values by analyzing the average NDVI values of the study area created with the downloaded Landsat Satellite Image dated 17.06.2014 before the road construction and the average values of those dating from after the road construction (20.06.2015, 22.06.2016, 25.06.2017, 12.06.2018, 15.06.2019, 03.07.2020, 06.07.2021, and 15.06.2022). Fig.s 7, 8, and 9 show color infrared images and NDVI values for the specified years.

In the 9 years between 2014 and 2022, there are minimal differences in NDVI values. According to Fig.10, there were no significant differences between the NDVI values before and after road construction, and the maximum NDVI average increased. It was revealed that the ring road construction had no effect on plant health in the peripheral rural area. Therefore, the ring road had no negative impact on the agricultural area.

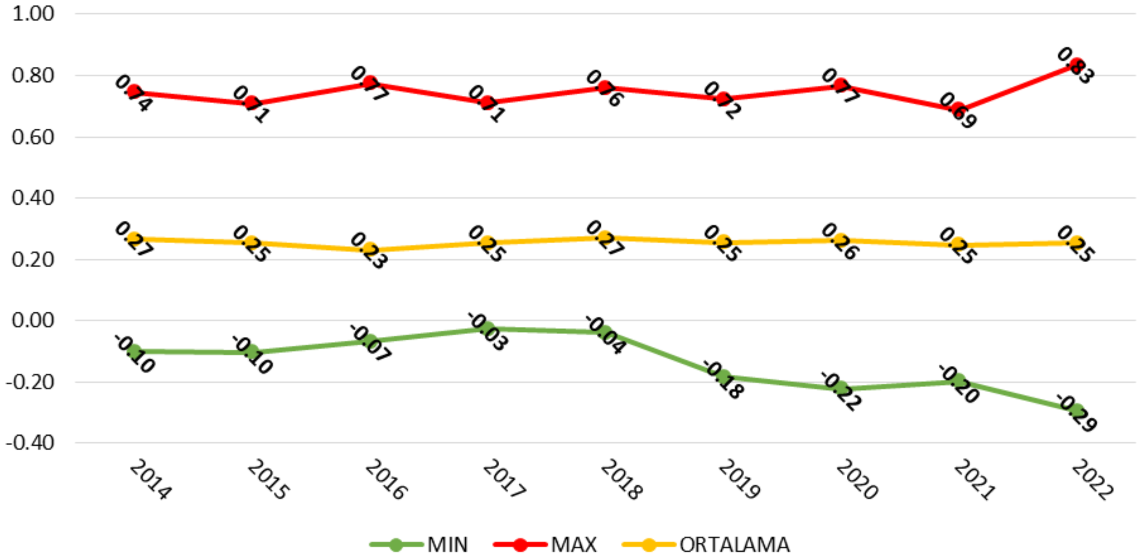

Fig.10 Changes in plant health in the study area over the years

Variance analyses showed a p-value of 0.094 ($p > 0.05$). Accordingly, Fig.6 shows no problem in plant growth in the study area during the 9-year monitoring period; maximum plant health data increased by 12.1%, whereas the average NDVI data decreased by only 0.7%. The cases where NDVI values showed slight variations in different years were determined, by on-site investigations, to be related to seasonal droughts, cultivation status, and irrigation of agricultural lands.

As seen in Fig.s 7, 8, and 9, the red areas in the images show areas with good plant health, and over the 9 years, there was no visible land use change other than the addition of the ring road.

In Fig.11(a), it is seen that the plant presence increased in the infrared images created by the combination of the bands between 2014 and 2022. We determined that some agricultural lands cultivated in 2014 were not cultivated in 2022 or that agricultural lands not cultivated in 2014 were cultivated in 2022, as in Fig.11, based on satellite images and on-site investigations.

The difference in plant presence and health was revealed as increasing and decreasing areas in the analysis of change, as in Fig.11d. In Fig.11c, the unchanged areas are indicated with yellow tones close to 0. Areas with agricultural lands that were not cultivated in 2014 but cultivated in 2022 and areas with increased plant health are close to -1, areas whose agricultural quality deteriorated due to roads, and areas with agricultural lands that were planted in 2014 and were not cultivated in 2022, with green color tones and close to +1. Agricultural areas that do not have any deterioration in plant health but have not been cultivated for various reasons will increase the minimum, average, and maximum NDVI values even more so when replanted. The dNDVI difference values will decrease, and the average variation will decrease.

The primary purpose of using the dNDVI (Differenced Normalized Vegetation Index) algorithm was to map regions that showed spatial variation in plant health within the agricultural area before and after road construction. The peripheral areas with improved and impaired plant health before and after the road construction were determined as red and green areas, as seen in Fig.11d. Green areas indicate those with declined NDVI values, in other words, areas where plant health is impaired or turned into residential and water areas. In contrast, red areas indicate areas with improved plant health. In addition, while examining satellite images in the area, we determined that greenhouse areas increased after road construction, and these areas appear in red in the dNDVI analysis. It was determined that plant health increased in 597.5 hectares of 1171.7 hectares, while plant health decreased in 574.2 hectares (Tab.2).

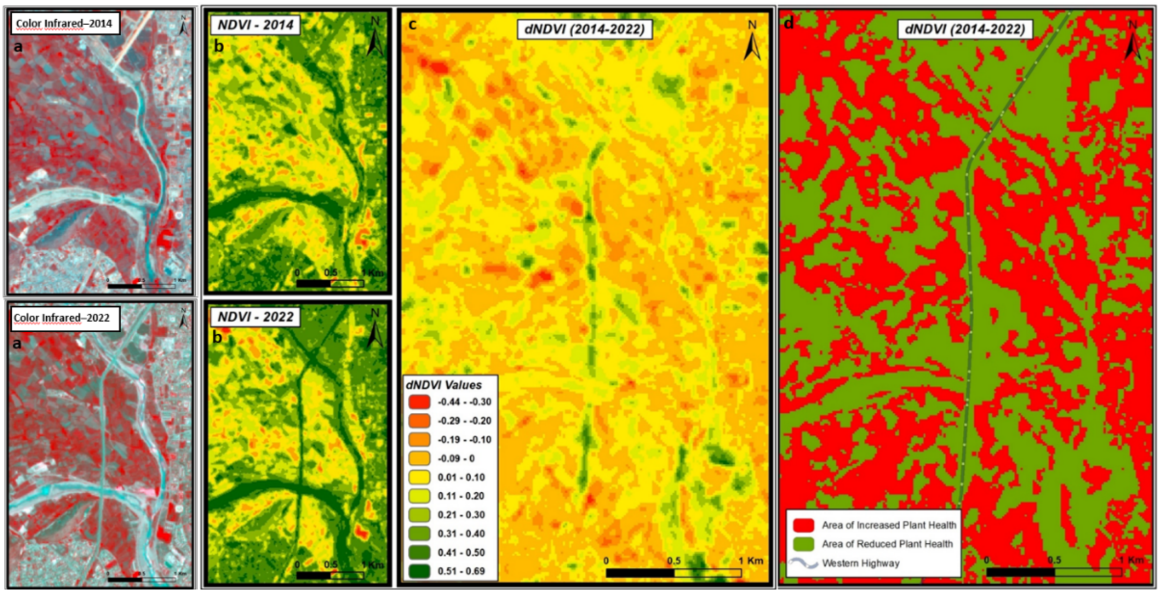

Fig.11 (a) Color infrared image before and after the change (b) NDVI analysis before and after the change (c) dNDVI results (d) Areas with increased and decreased plant health

Change of plant health (Hectares)	
Increase	597.5
Decrease	574.2
Total Working Area	1171.7

Tab.2 Changes in Plant Health by Land

5. Conclusion and findings

Our analyses, utilizing NDVI and dNDVI algorithms, infrared combinations, and dataset evaluations, indicate that the Western Ring Road in the northern Konyaaltı district of Antalya did not negatively impact plant health in the surrounding agricultural areas, nor did it diminish crop yield or productivity. These findings challenge the justification for rezoning agricultural lands based solely on assumptions of declining agricultural productivity. As a result, urban-rural dynamics should be assessed through an integrated part-whole approach, with planning strategies prioritizing conservation and sustainability. Ensuring that urban expansion follows rational and data-driven planning decisions will contribute to more sustainable development patterns.

Moreover, when planning a transportation network to enhance accessibility between urban areas, there is no inherent necessity to rezone peripheral agricultural lands unless clear evidence demonstrates a loss in agricultural productivity or land degradation post-construction. Transportation planning should involve rigorous analysis to determine whether routing through agricultural areas is the only viable option. If alternative routes exist, protecting agricultural land should be prioritized.

Furthermore, the mere decline of agricultural land quality should not be considered a sufficient criterion for rezoning an area for urban development. As observed in the case study, additional factors such as flood risk, earthquake susceptibility, and ecological balance must be thoroughly assessed. At this stage, GIS and remote sensing technologies play a crucial role in ensuring objective, comparable, and sustainable planning decisions. However, considering only physical-environmental impacts is insufficient for sustainable planning. Prior to making zoning or land-use decisions, it is essential to incorporate stakeholder opinions, including those with direct rights and influence in the affected area. This participatory approach ensures that planning decisions align with social, economic, and environmental considerations.

Additionally, as demonstrated in this study, large infrastructure projects not only generate immediate environmental effects but also shape the microform of urban development in the long term. A limitation of this study is that the impact of the Western Ring Road was assessed solely concerning its effects on surrounding agricultural areas and plant health. Future research should adopt a broader perspective, evaluating the interaction between transportation infrastructure and urban growth within a larger spatial framework. This would provide a more comprehensive understanding of transportation-land use dynamics, contributing to more sustainable and holistic planning decisions.

Finally, our findings align with previous studies emphasizing the adverse effects of unregulated urban expansion on agricultural lands and the importance of defining clear planning thresholds to control development (Esopi, 2018; Samat et al., 2020). Without well-defined natural and artificial boundaries, zoning decisions may fail to remain permanent, leading to ongoing urbanization pressure on agricultural lands and ecologically sensitive areas (Tondelli et al., 2017). Our research reinforces the necessity of long-term strategic planning that integrates both environmental and socio-economic considerations in land-use decisions.

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