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Exploring Causality and Impact between Romanian Urban Real Estate Developing and Green Spaces

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Abstract. *The real estate sector has experienced rapid growth in all developed and developing countries in recent decades, sometimes with year-on-year percentage changes exceeding 2 digits. However, today, the rapid growth in recent years must also consider the objectives of sustainability and reducing carbon dioxide emissions by introducing as many green spaces as possible. Thus, omitting the inclusion of these components results in the acceleration of global warming. The main objective of the research is to identify the positive or negative impact of real estate development on green spaces, focusing on two indicators: the number of private homes in urban areas at the end of the year and the surface area of green spaces in urban environments. For both indicators, the time component is between 1996-2023, and the data are taken for each county in Romania. In the analysis, the data is normalized and described to understand the context of their evolution. Statistical tests, such as the Augmented Dickey-Fuller test, determine the stationarity of the time series. The Akaike Information Criterion test identifies the optimal number of lags, through which the causality between the two indicators is tested using Granger causality. Along with the main objective, the research presents previous studies to understand whether the integration of green spaces with real estate development is considered.*

Keywords: Green Spaces, Real Estate, Sustainability, Causality, Tableau.

Introduction

The real estate sector is a key driver of economic growth. On the other hand, data from the U.S. Energy Information Administration shows that it consumed 29% of the total energy in the USA in 2020, making it a significant contributor to carbon dioxide emissions. In this context, the introduction of the green component, respectively green spaces, along with the energy efficiency component in real estate development, become essential for a sustainable environment (Haddad et al., 2024).

In the context of accelerated real estate development, real estate development and green certification, officials must provide residents with a long-term sustainable and green development

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plan (Anguelovski et al., 2024). Thus, solutions such as Nature-Based Solutions have emerged, considered necessary investments for sustainable urban development. These solutions propose the integration of parking lots with green spaces and rooftops with green spaces, contributing to improving the quality of people's lives (Chayanika Perera et al., 2024).

The rapid growth of the real estate market is evident in both the United States and Europe, particularly in countries like Italy, Belgium, Germany, the Netherlands, and the United Kingdom, where real estate agents continue to expand their wealth portfolios. This trend is driven by home purchases facilitated through loans in countries like Germany, the Netherlands, and the United Kingdom (Chi-Wei Su, 2010).

Given the role of green spaces in urban development and their impact on quality of life, this research seeks to examine whether the extent of green spaces in Romania has been influenced by the rapid urban development of the past two decades. The primary objective is to employ quantitative methods, such as Granger causality, to identify the relationship between urban development and green spaces, along with descriptive methods, including graphical visualizations created in Tableau, to analyse the evolution of these two indicators. Additionally, the research will incorporate specialized studies to provide a comprehensive perspective on the relationship between these two variables and how this connection is interpreted in other scientific papers.

Literature review

To analyze the impact of real estate development on urban green spaces (UGS), reliable data is crucial. Huang et al. (2021) note the lack of globally precise maps and address this by creating a comprehensive UGS map for 1,039 cities in 2015 using 51,494 Landsat images and the Google Earth Engine (GEE) platform. They calculated two indicators: urban green space coverage (UGSC) and accessibility (UGSA), highlighting regional disparities – cities in Europe and the eastern U.S. generally had high UGSC (>60%) and UGSA (>80%), while Western Asia and North Africa showed much lower levels. Urban green spaces vary in function and services. Degerickx et al. (2020) developed a typology with 23 functional types and demonstrated a methodology for mapping UGS by function. Teo et al. (2023) developed a novel land cover fraction map for Singapore spanning from 1990 to 2020, utilizing high-resolution satellite imagery. Their analysis revealed an overall decline in greenery, encompassing tree cover and grass/shrub cover, within public housing towns in Singapore. Simultaneously, there was a significant increase in built-up areas observed across all towns. Gavrilidis et al. (2022) utilized Geographic Object-Based Image Analysis and Random Forest classification to identify and extract urban green areas at the city level for Bucharest.

The relationship between urbanization, which inherently drives real estate development, and greenery is defined by two simultaneous yet opposing processes: urban expansion encroaching upon green spaces, and urban greening initiatives aimed at the creation of new parks and green areas (Teo et al., 2023).

Urbanization drives UGS reduction, particularly in economically less developed regions, according to Derdouri et al. (2025). Their study of eight cities over 1990–2020, using GEE data, revealed UGS declines in six cities, including Berlin (36% to 27%) and Casablanca (21% to 6%). Notable exceptions were Sydney, where UGS rose from 12% to 23% due to the Sustainable Sydney 2030 plan, and Mexico City, where UGS increased from 5% to 9% under its Green Plan. The authors call for urgent, comprehensive urban greening strategies to promote sustainable urban environment.

The relationship between greening and new residential development in 26 cities across Europe and North America has been studied by Anguelovski et al. (2024). The authors conclude that, in most cases, greening overall is "effectively a driver for development" (greening can predict development).

The surface area and number of urban parks in Romania significantly increased during the Socialist period, as noted by Badiu et al. (2019), though a decline followed the fall of the regime. An analysis by Gavrilidis et al. (2022) concludes that residential neighborhoods planned during the communist era have higher levels of greenery compared to those developed over the past three decades. After the removal of certain administrative restrictions that had limited urbanization in Eastern European countries during the Socialist period, urbanization intensified. With the transition from a planned economy to a market economy, a somewhat unregulated process of construction began, often targeting inter-block spaces that were green areas during socialism. Privatization and restitution policies further contributed to the reduction of green areas, as owners developed restituted parcels, circumventing preservation measures and local protests (Badiu et al., 2019; Stanilov, 2007; Hirt & Stanilov, 2007).

The growing density of urban development has significantly harmed urban green spaces. To some extent, this effect has been mitigated by the expansion of cities into abandoned agricultural land in their immediate peripheries (Grădinaru et al., 2015). These areas typically have lower building density, and a much higher percentage of green spaces compared to city centers.

Housing market studies show a growing appreciation for proximity to parks or neighborhoods with lower building density and more green spaces. Kronenberg et al. (2023) investigated developers' activities around 107 public parks and green squares in Łódź, Poland, between 2011 and 2021. They conclude that developers benefit from the demand for proximity to urban green spaces, as people are willing to pay a premium to live near them. Consequently, green growth is expected to result from new green residential developments. However, it is important to recognize that this growth sometimes comes at the cost of informal green spaces, which are being replaced, and that developers capitalize on the external benefits provided by the existing green spaces. A hedonic pricing analysis by Teo et al. (2023) concluded that the marginal effects of greenery on real estate prices were positive across all three decades (1990-2020), with greenery contributing an increasingly larger proportion to the resale price in Singapore. Yen et al. (2023) apply a similar approach to property prices on the Gold Coast, Queensland, Australia. Their findings indicate that residents are not merely seeking green space but expect green infrastructure to play an active role in their daily lives.

While increasing green spaces per capita is an important consideration, it should not be seen as a primary target for achieving cities' sustainability goals (Badiu et al., 2016). A comprehensive strategy for urban green infrastructure (UGI) is crucial, although this need is not yet widely acknowledged by many urban practitioners. Unlike traditional green space planning, the UGI approach emphasizes interconnectivity and the creation of integrated green networks, a concept that remains insufficiently implemented in practice (Gavrilidis et al., 2020).

Methodology

The primary objective of the current research is to analyse whether the number of real estate developments in the private sector in Romania influences the total surface area of green spaces (measured in hectares), with both factors focusing exclusively on urban areas and categorized by the criterion of counties. In order to achieve the objective of the research, a series of steps need to be completed.

First, the data set will be selected, with the two indicators in the foreground. On the one hand, the number of houses in the urban area at the end of the year will be divided by counties, and the representative analysis interval is the period 1996-2023. Although there is data for the years 1990-1995, a very large inconsistency was identified, which led to their elimination, for better governance, along with Sălaj County. On the other hand, the second indicator of the data set is the surface of green spaces expressed in hectares. Green spaces, including parks, forests, and green developments in urban habitable areas, were analysed for the period 1996–2023. The data, as with the previous indicator, were also categorized by counties, excluding Sălaj County.

Evaluating the relationship between the two indicators is essential to understand whether real estate development in Romania has considered the green component, respectively whether developments in Romania have been sustainable. At the same time, the objective of the research is to verify the nature of the effect of real estate development, whether positive or negative.

In the first stage of the analysis, a descriptive dashboard will be built on the two indicators in the business intelligence program Tableau, in order to understand the evolution of each indicator over the years. At the same time, it will be checked if there are missing values in the data. The remainder of the analysis will be conducted in Python, with the results exported to Tableau for enhanced visual presentation and interpretation.

As a result of understanding the evolution of the two indicators, we will start by preparing the data set to evaluate the link between the two indicators. Since we are talking about 2 time series, we will first test their stationarity using the Augmented Dickey-Fuller (ADF) test. For counties where the time series is non-stationary, series differentiation will be applied as many times as needed. Since the data series will be divided into stationary and non-stationary, only non-stationary data series will be used as the objective of the research, using a certain unit of measurement. On this data set, the influence of the development of the number of real estates on green spaces will be tested, using Granger causality, and for counties where there will be Causality between indicators, a new dashboard will be built in Tableau to understand how the causality was generated, positive or negative. Granger causality is also used to develop research that supports the link between urbanization and the climate effects it generates, for example, whether real estate development affects green spaces in China, where uncontrolled and sustainable urbanization has generated changes in temperature and precipitation above normal levels (Qikang Zhao et al., 2024).

Results and discussions

The data set was taken from the Tempo.ro website and includes data taken for the period 1996 - 2023. These are divided into the counties of Romania, to which the Municipality of Bucharest is added. The set follows two indicators, "Number of houses" and "Surface of green spaces". Initially, the data set is checked to determine if there are missing values that need to be replaced. Due to the lack of data on the indicator for Sălaj County, it was eliminated from the analysis. If the data had also been present for this county and there had only been a lack of one or two years, the replacement of the missing values would have been carried out either with the average of the years for this county or with the rolling mean. At the same time, the existence of outliers and their elimination will not be tested, having a time series for each county.

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A dashboard is created in Tableau to visualize the data set for each indicator, with the results for the growth rate 2023/1996 of the number of houses presented in Figure 1:

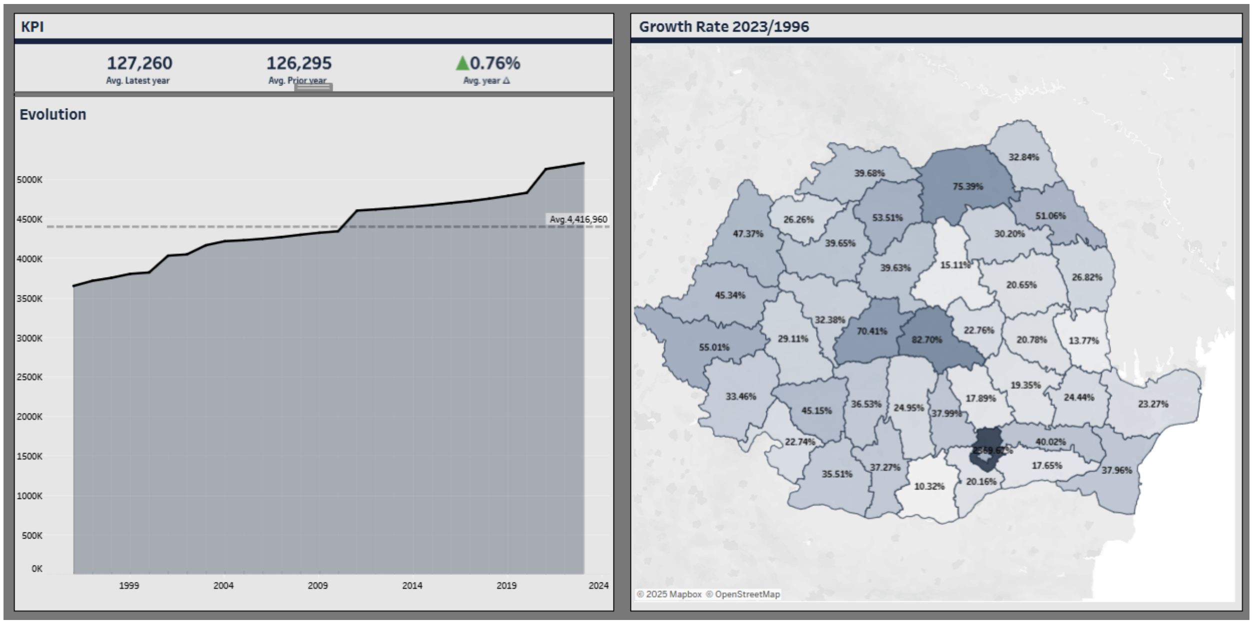

Figure 1. Dynamics and Growth Rate 2023/1996 of the Number of Houses in Romania by Counties

Source: Authors' representation in Tableau based on the dataset acquired from tempo.ro.

Between 1996 and 2023, the real estate market had a period of growth, only with an upward trend. However, in 2002 compared to 2001 and 2000 compared to 1999, a small decrease was observed compared to the previous year, the average total number of houses in the private sector being 4416960 houses in approximately the entire country. The average by county in 2022 is 127260 houses in 2023 compared to 126295 in 2022, the real estate market marking an increase of 0.76%. Between 1996 and 2023, the largest percentage difference is found in Ilfov county, which is normal, due to the limited development space of Bucharest, Ilfov benefiting from a much larger development space. For this, the number of houses between 1997 and 2023 increased approximately 23 times. The next increase is given by Brașov County, with an increase of 82.70%, followed by Sibiu and Iași counties with an increase of 70%.

The dataset for the "Surface of Green Spaces" indicator is presented as follows in Figure 2.

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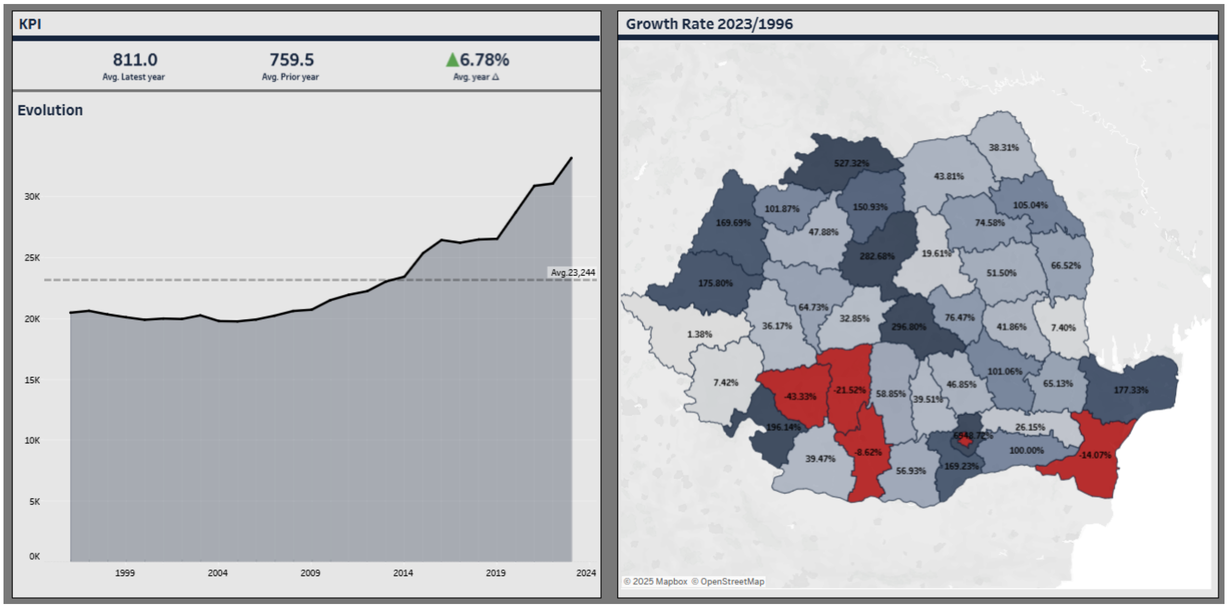

Figure 2. Dynamics and Growth Rate 2023/1996 of Surface of Green Spaces in Romania by Counties

Source: Authors' representation in Tableau based on the dataset acquired from tempo.ro.

At the national level, the evolution of green space areas in Romania showed a slight decline between 1996 and 2005, with a small increase in 2003. Starting in 2005, the values of green spaces in Romania exhibited significant increases, following a consistently upward trend. The average green space area throughout the entire study period was 23,244 hectares. In 2023, there were, on average, 811 hectares of green spaces per county, this being an increase of 6.78% compared to 2022, when there were only 759.5 hectares. In the case of the percentage change between 1996 and 2023, there are 4 counties and the Municipality of Bucharest that had a decrease in green spaces between 1996 and 2023, these being Gorj, Vâlcea, Olt and Constanța. There are also counties where the growth was more than 200% in the analysed period, such as Maramureș, Brașov and Mureș.

According to the dashboards containing the evolution line chart, an upward trend is identified for both indicators and, since it is a time series analysis, the ADF test will be run to identify if the data series present non-stationarity. The ADF test is run individually for each time series of a county, and for counties where the p-value is less than 0.05, the ADF test identifies stationarity. The results for each indicator are presented in Figure 3.

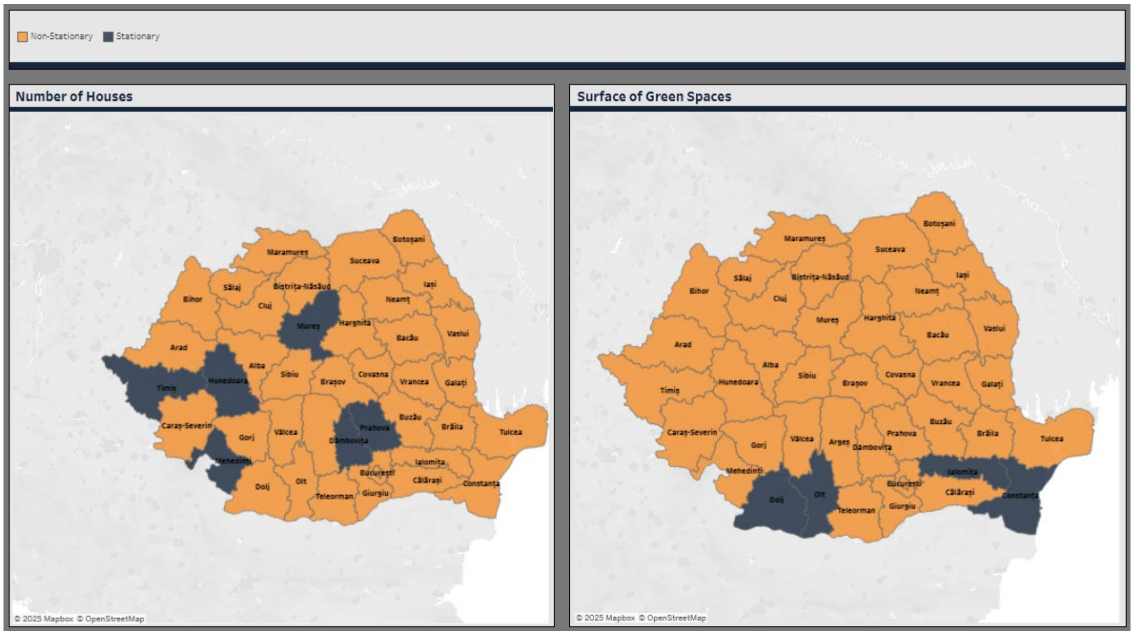

Figure 3. ADF Stationarity Test

Source: Authors' representation in Tableau based on the dataset acquired from tempo.ro.

According to the results of the ADF test for both indicators, the time series for the "Number of Houses" exhibits stationarity in the counties of Timiș, Hunedoara, Mehedinți, Dâmbovița, and Prahova. However, the remaining 35 counties, along with the Municipality of Bucharest, are characterized by non-stationary data series. For the "Surface of Green Spaces," the number of stationary data series is smaller, with stationarity observed only in the counties of Dolj, Olt, Ialomița, and Constanța.

To maintain data consistency and due to the difference in unit of measurement, a differentiation will be made for non-stationary counties to bring the data series to the stationary level, only non-stationary counties will be kept, the stationary ones being eliminated. If a county is stationary in the time series of the "Number of Houses", then it will also be eliminated from the "Surface of Green Spaces" data series, thus eliminated: Dolj, Olt, Ialomița, Constanța, Prahova, Dâmbovița, Mehedinți, Timiș, Hunedoara and Mureș.

First-order differentiation will be applied using the formula:

$$y_t{}' = y_t - y_{t-1} \text{ (1), where}$$

y_t – the value of the variable at time t;

After the first differentiation, the stationarity of the series is tested again, some of the counties still showing nonstationarity, thus applying second-order differentiation where appropriate using the formula:

$$y_t{}'' = y_t{}' - y_{t-1}{}' = (y_t - y_{t-1}) - (y_{t-1} - y_{t-2}) \text{ (2).}$$

After transforming both data series to achieve stationarity through differentiation, the Akaike Information Criterion test is employed to determine the optimal number of lags for testing Granger causality for every county. Subsequently, Granger causality analysis is performed for the two variables, with the results presented in Figure 4.

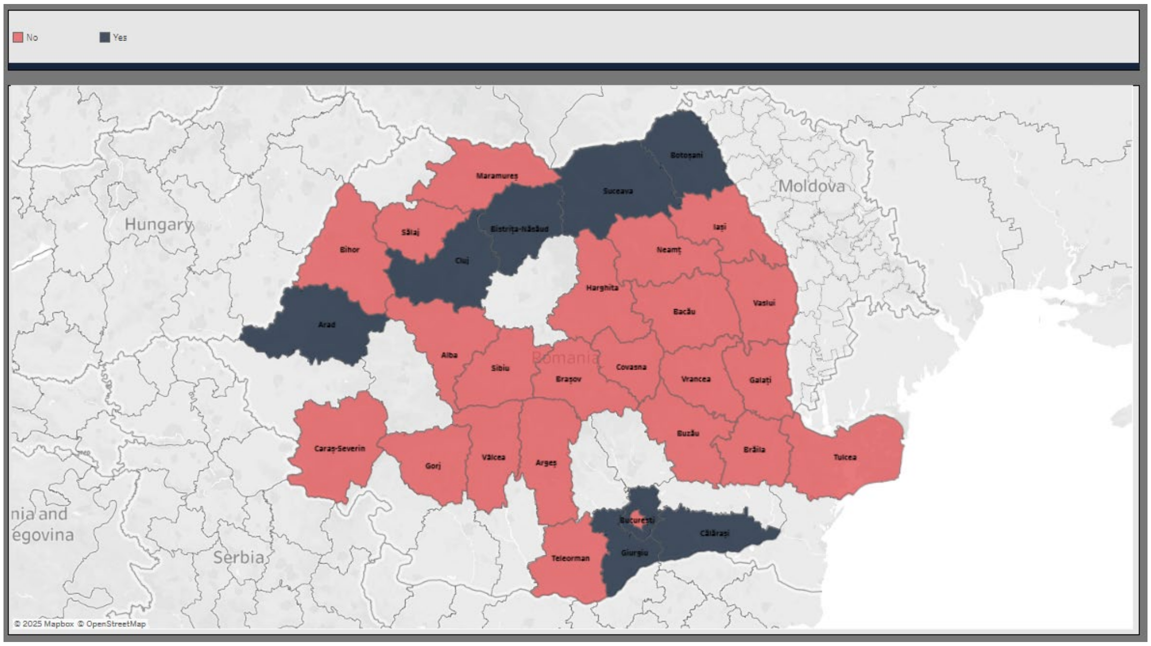

Figure 4. Granger Causality

Source: Authors' representation in Tableau based on the dataset acquired from tempo.ro.

There are 8 counties where Granger causality exists, and in order to understand the causality between the "Number of houses" and the "Surface of green spaces", a combined chart (Figure 5) has been constructed.

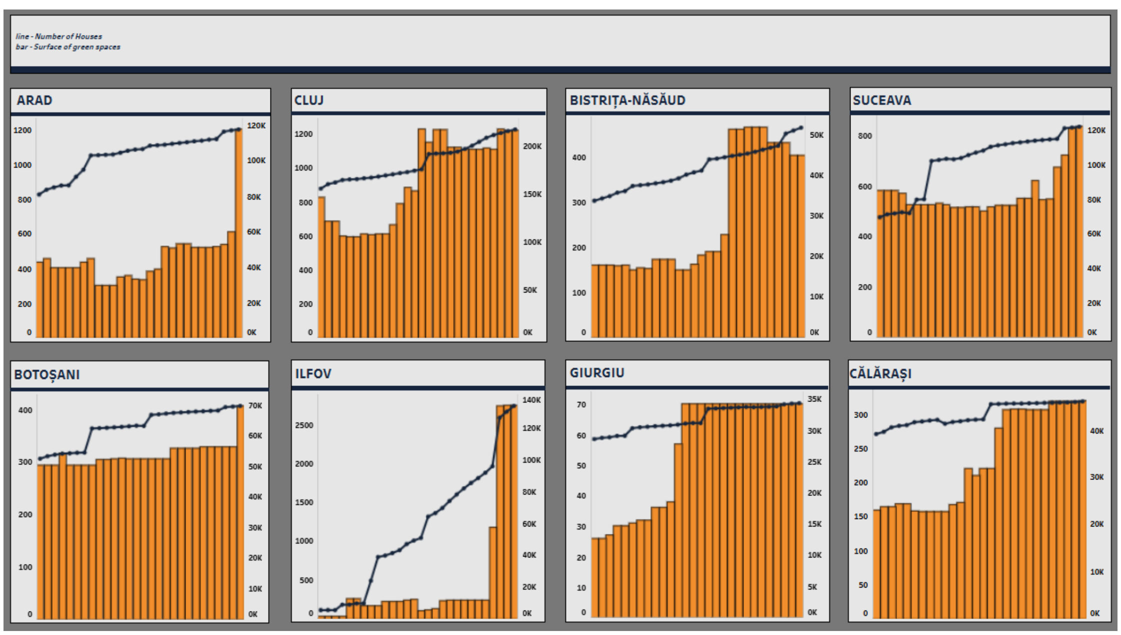

Figure 5. Granger Causality – Yes counties

Source: Authors' representation in Tableau based on the dataset acquired from tempo.ro.

In Arad County, it is observed that green spaces have been influenced by private real estate developments. In the early years, real estate developments increased, but the surface of green spaces decreased inversely to the relationship of real estate developments. In contrast, in 2023, a very large increase in green spaces is observed, probably due to the opening of a green area, such as a park or a forest near residential areas. In general, all counties show an inverse relationship of green space development until 2012, namely with the increase in real estate development, green spaces actually decrease, as is the case of Cluj, Bistrița-Năsăud, Suceava, Ilfov and Călarași. In counties such as Suceava and Călarași, the number of lags is very high, resulting in a very close relationship between the two variables, real estate development directly negatively affecting the surface of green spaces in the county. Giurgiu County serves as a benchmark for sustainable development. The strong correlation and upward trend between the two variables indicate that real estate development has taken into account the expansion of green spaces.

Since 2012, most counties have had a double increase in green spaces, which leads to the conclusion that the laws regarding green spaces are changing, and counties are starting to increase their green area. An illustrative example where buyers have started looking for homes that are focused on green areas is that of Ilfov County, which is around Bucharest. In this county, the price of land is lower than in Bucharest, allowing the development of parks and forests within the county and around real estate complexes.

Conclusion

Between 1996 and 2023, the private real estate market in Romania had a constant growth. However, there was also a change in the upward slope during 2008, when the global real estate crisis occurred. After 2008, the number of real estates continued to experience a positive percentage change until 2023 when the average percentage difference at county level between 2022 and 2023 was only 0.76%. Between these two years, an increase in the real estate stock was noted, due to external factors, such as the emergence of a new crisis, the war in Ukraine or political causes. At county level, between 1996 and 2023, the stock of private housing also increased by over 70% in some counties, such as Ilfov, Sibiu, Iași and Brașov.

The evolution of the surface of green spaces had a slightly downward slope until 2004. Romania's accession to the European Union contributed to changing the downward slope into an upward one. Thus, Romania complied with the European Union norms, the notion of sustainability being especially visible between 1996 and 2023, where the average per county of the surface of green spaces increased by 6.78%. However, there were also areas where green areas had a negative percentage change, such as Ilfov, Constanța, Olt, Gorj, Vâlcea.

The main objective of the research to demonstrate the negative or positive impact that real estate development has on green spaces was demonstrated using Granger causality. Therefore, negative real estate development was visible in counties such as Arad, Cluj, Bistrița-Năsăud, Călărași, where until 2012, the surface of green spaces decreased and was affected by real estate development. There are also counties such as Giurgiu, which have considered the objective of sustainable development since 1996. Starting with 2012, counties such as Arad, Cluj, Bistrița-Năsăud, Suceava, Botoșani, Ilfov, Giurgiu, Călărași have doubled their surface of green spaces, due to the new urban codes imposed by the European Union.

Regarding the main limitations of the research, they consist in limiting the data to the county level and not to the city level. Also, another limitation consists in having the observations to the year level, not to the level of at least semester, because the tempo.ro platform provides aggregated data only at the year level divided by counties, limiting them to the year level. Although the Granger causality was done for each county separately, not taking into account other counties, increasing the granularity of the data at the semester level could reduce the variation of the model. A monthly aggregation level could not be used, because the changes would not be major, the development of a green space taking a long period of time.

The research can be expanded to include green energy, not just green spaces, by incorporating the segment of buildings in the energy A class. This class means to implement solar panel systems, ventilated facades, etc. respectively utilities that reduce conventional energy consumption. The study could also include the type of green space as a variable, as trees will reduce carbon dioxide emissions much more than planting only grass or creating mixed parking lots (green spaces and concrete). Introducing more variables could also contribute to understanding the respect for the green ecosystem by real estate developments. In addition to Granger causality, one can also test the future impact that real estate development may have on green spaces, namely predictions can be made using machine learning algorithms such as LSTM to predict a year and test Granger causality later, so if the real estate market grows by "n"%, then green spaces will be influenced or not.

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