QUESTIONING URBAN SPACE EVOLUTION IN ROMANIA'S SMALL AND MEDIUM-SIZED CITIES - A DEEP LEARNING CASE STUDY

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ABSTRACT

Automation processes grew vigorously in GIS-driven analysis and became more and more popular in the last decade. Deep learning and GIS are now used more and more often in all areas, from agriculture, hydrology to urbanism, offering the researcher a quick yet detailed and complex analysis and output. To give a quick overview, deep learning works similarly to traditional supervised classification on satellite images, except that with each iteration, the model becomes more adept at identifying patterns, such as land use, and the samples collected for the classification can be later used for another area..

The small and medium-sized cities of Romania, that are facing serious dificulties nowadays, are shifting now from their classical role to a more peripheral role, by losing their main industrial functions in the last three decades, since the fall of communism.

In our analysis, deep learning object classification is used to detect the extent of Romania's urban built-up areas in the small and medium-sized towns. Our main purpose is to underline the method which uses deep learning analysis,with emphasis on understanding the real extent of built-up places of the above-mentioned cities. The main output of the study is a clear overview of how the urban space is structured in our cities and how they changed in the last decade. Of course, there are studies and analyzes that showed how land use changed, such as Corine Land Cover, but the scale of the studies done are not relevant in our area of study, hence the necessity to have a detailed scale to underline precisely the changes.

Keywords: deep learning, small and medium cities, urban growth

INTRODUCTION

Small and medium sized cities always played a substantial role in every country’s urban system. They are meant to be the main binder between urban and higher urban, their hinterlands are supposed to overlap all the rural areas of a country, to fulfil the basic and immediate needs of the population. Still, the debates circling the academic sphere are not yet focused on the study of the small and medium sized cities, the latest being largely neglected [1].
Urbanization is a complex process of change of rural lifestyles into urban ones [2]. Romania’s urban system did not make an exception in this effort – from the late 1960’s, the total number of cities rose from 188 to 320, a tendency shared by other east European countries [3]. From the grand total of 320 cities, more than 86% (278 towns) have less

than 50.000 inhabitants – according to the 2021 National Statistical Institute, counting in our analysis as small and medium sized.
Over the last three decades, Romania's transition from a centralized to a market economy has resulted in a significant chaotic reorganization of urban land use, facilitated by the phenomena of urban sprawl with hardly any regulation. As a result, scholars and policymakers must work together to better understand the spatial evolution of these cities, which serve as a cornerstone for integrating rural space with urban functionality.
Previous papers regarding the urbanization process [4-6] showed that the phenomenon integrates four stages – urbanization and suburbanization in the growth process and desurbanization and reurbanization. Mostly, this classification is used the Functional Urban Areas (FUAs) but in Romania's context, more than half of our cities fall in the hinterland of regional cities (more than 50.000 inhabitants).
Hence it is crucial to understand if there is a causality between proximity to a big city and urban space evolution of our small and medium-sized cities and if the growth is not caused by the suburbanization phase of a FUA.

DATA AND METHODS

One would argue that in order to measure the spatial extent of a city during a given period of time, is it enough to only look at the % of the urban sprawl but to fully underline the extent of space evolution in our small and medium sized cities, we have to take into consideration a broader number of indexes and methods. Our paper uses both statistical data, such as population dynamic, the rate of urban sprawl growth but most important, satellite imagery.

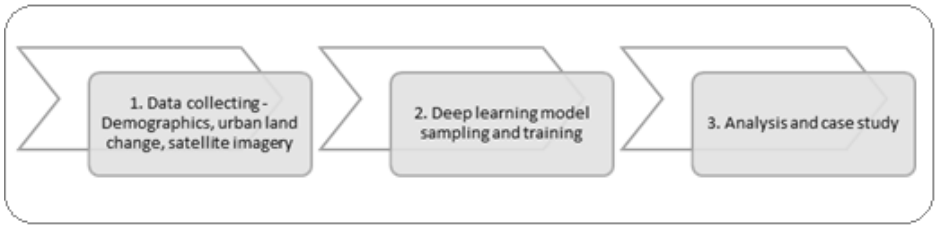

Figure 1 - Phases of the methodology

As the above figure states, our methodology consists of three main steps: 1. data collecting, in which we obtained all our data and indices that we used for our analysis, 2. gathering samples for later training our deep learning model to detect changes and the last step, 3. A100nalysis of the results and detailing of a case study to have a better understanding of the outcome of our work.
The period of time chosen was 2010-2018, due to the availability of data, time consistency varying for satellite imagery due to the duration of a full flight to be completed (+- 1 year differences for the full surface of Romania).The data regarding the population dynamic was extracted from the National Statistical Institute of Romania in the interval stated earlier and the rate of urban sprawl growth was extracted from Copernicus Land Monitoring Service for our cities. There are also some limitations regarding the data used – the changes in land use provided by Copernicus Land Monitoring are mapped only if they are larger than 5ha, so it may be difficult to have mapped all the changes for a small community.
In order to minimize the errors that can show up from the indexes collected, we use our deep learning model to fully identify the constructions that rose in our chosen period of

time. For this particular case, we used Mask R-CNN, a Convolutional Neural Network (CNN) and state-of-the-art in terms of image segmentation and instance segmentation, used mainly for object detection that has two outputs for each candidate object, a class label and a bounding-box offset [7] that fits best our purpose.
There have been some previous papers that used the same methods regarding the deep-learning model, varying from general land-use classification [8], housing [9] and other applications [10][11]. The vast majority of papers cover overwhelmingly physical geography subjects so is it paramount to try to cover our field of study.
Our deep-learning model was trained with the help of around 2000 samples, taken from both 2010 and 2018 images with 0,5m pixel dimension to accommodate changes of color given by different seasons in which the images were collected. The backbone of the model chosen was RESNET50, the resolutions of the chips (the samples collected) being 224x224 pixels. For the number of trainings carried out by our model (7) we managed to obtain a confidence score of roughly 85%, the model stopped itself when there was no more improvement left. [Figure 1].

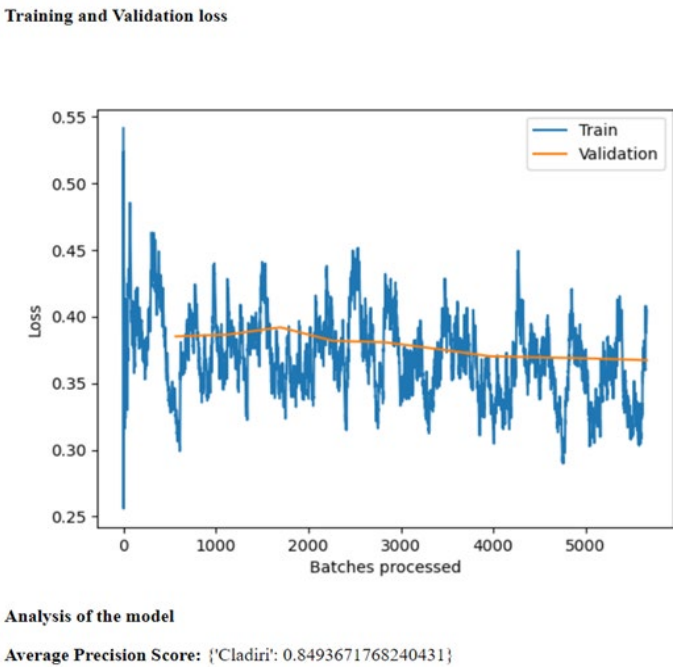

Figure 2 – Snapshot of the model metrics showing the batches processed and the average precision score

The samples collected for our model were grouped into a single class, called buildings which incorporated both building blocks and individual houses, so our model can identify only the buildings that are intended for living. All the data collecting and deep-learning analysis was carried out with ESRI ArcGIS PRO.
The main purpose of our study is to – 1) find is there is any correlation between population dynamic and urban space growth rate to see if the process is indigenous or exogenous, 2) how much of the urban space growth rate is given by the living space and 3) what category of cities registered the most growth in the period of time chosen.

RESULTS

Looking up to Romania's demographics for the last 15 years, there was a constant decrease in terms of population both for small and medium-sized towns and the other bigger cities. In percentages, our cities lost roughly 5% when it comes to residents [Figure 2] but gained an overall 6% increase in built-up areas [Figure 3]. The logic would dictate that the expansion of the built-up areas is sign of urban development, but it cannot lack the demographic raise in numbers.

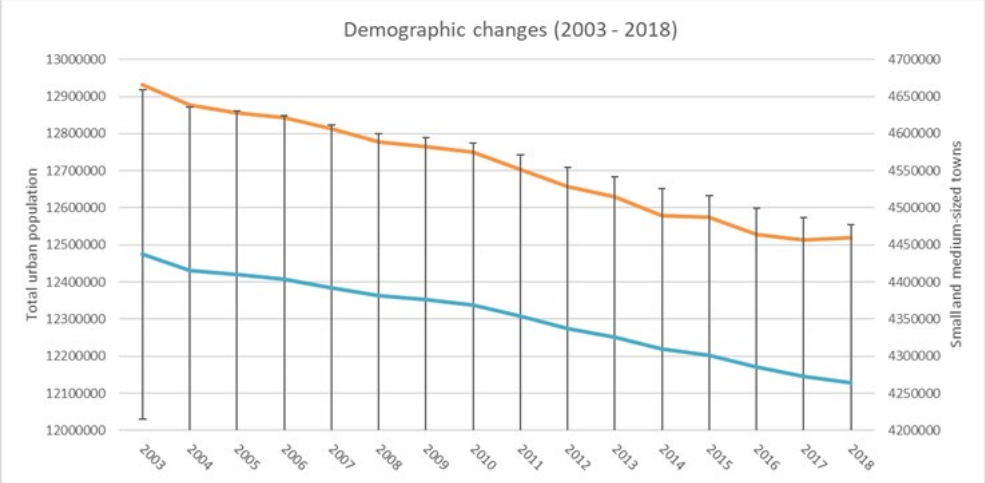

Figure 3 – Demographic dynamic between 2003 – 2018 of small and medium-sized towns.
Source: National Institute of Statistics1*

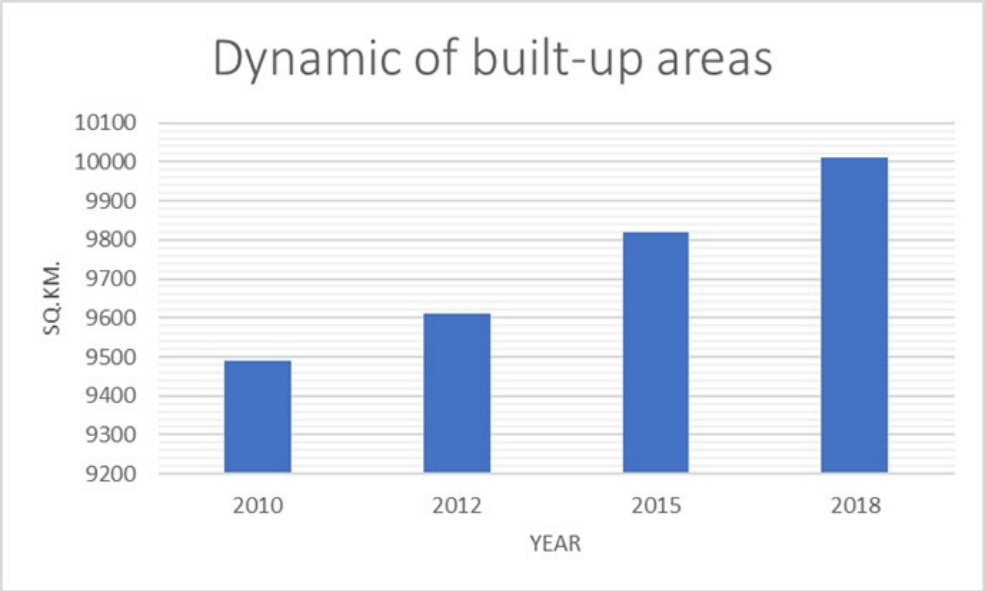

Figure 4 – The dynamic of built-up areas in small and medium sized towns (2010-2018)
Source: Copernicus Land Monitoring Services2*

In order to underline our main goals of our paper, we ran a series of regression analyzes to try to find a link between our indices. Our dependent variable was the urban growth rate and we confronted it with population dynamic and travel distance to a higher ranked city. First, we carried out the regression among all of our cities and in both cases, with 95% confidence, we found little to none causality between the beforementioned data, the

Multiple R resulted was 0,44. Second, we narrowed our analysis to the sattelite cities of Bucharest, finding even less causality, with a Multiple R score of 0,42.
In our case, it is arguable that one general measurement fits all of the 278 cities or even 8 cities, that is why we have to apply a bottoms up approach to best describe the local context. Thus, we selected a city that scored an increase in population and built-up areas in the last 15 years.

Figure 4 – Old buildings and new buildings in the city of Chitila.

The city of Chitila is one of Romania's latest cities, which was a rural commune until 2005. It is one of Bucharest's satellite cities, being only 9 km away from the capital city's center. According to our data, the city had an increase of 31% in population and around

38% increase in built-up areas. It is common that a sattelite city of one metropolis to actually act as a typical neighborhood, going by the name of commuter town or exurbs [12][13].This typology of city is less probably to develop its own industry or a dense network of services turning the focus to expand urban sprawl, both individual and collective housing. Altogether, in our opinion, this is the propitious setup to further investigate if there are strong correlations between the factors investigated.
As a last part of our analysis, we ran our deep learning model that was trained to identify housing buildings from both 2010 and 2018 images, the main output being the boxes that frame the buildings. In the map above [Figure 4] we mapped the buildings that were identified through our analysis. The ones colored with red, as the legend of the map says, are the buildings found by 2010 and, on the other hand, the blue color highlights the new buildings that were built by 2018. There is a clear demarcation between the old urban core which lies on both parts of the main road that connects the city to the country capital and the new communities that rose like suburbs of the city, in the south-western and northern outskirts of the city. There are also some interstitial spaces that were filled during this period of time, furthering the densification of the city.
In quantitative terms, the housing surface increased with nearly 21%, from 2721 buildings in 2010 to 3356 in 2018, the biggest majority of them being represented by individual houses grouped in new neighborhoods. We strongly believe that in this case, the proximity to Bucharest heavily influenced population growth and urban space evolution. As we mentioned in the beginning of this chapter, in the evidence of Copernicus Land Monitoring Service the city of Chitila had registered a growth of 38% in built-up area. As our results mentioned more than half of this percent is represented by housing buildings

CONCLUSIONS

The transition from a centralized economy and authoritarian regime to a market economy and democracy in Romania was swift and brutal, accompanied by dramatic changes in the social and economic environment that had a significant impact on the spatial evolution and transformation of small and medium city spatial structures.[14]
Urban space evolution can be sometimes difficult in terms of choosing the right scale of study, data and methods. As we saw earlier, the data available can not describe the local context and it is necessary to adapt our framework to find out the precise numbers behind the situation.
Regarding the deep learning procedures, there are of course advantages and disadvantages: the main advantages consist of the versatility of the deep learning model, that can perform better and better by each iteration, it can work with any type of images, but most importantly is the most precise and cost-effective technique that it is known by this moment to rapidly identify structures from satellite imagery. We should also name the disadvantages of using deep-learning, that can come along with using the technique. The procedures require technical proficiency, it is resource consuming (both time and hardware) and lastly, can underperform when the satellite imagery has different color palettes, being highly required to pre-process the imagery data.
As we saw from the results, the city of Chitila had registered quite a significant urban expansion in just 15 years. It was quite clear from the beginning that increase in population and proximity to Bucharest would generate a higher demand on the real estate market, the future-urban spaces being a great future perspective. We should also underline the fact that, as a former rural community and part of a county that was formerly known as the Agricultural Sector of Bucharest, the city had vast fields that were occupied by

crops that were supplying Bucharest. Of course, the real estate projects benefited first, the prices after the economic crisis from 2008 that were at a historical minimum paved the way to fast urbanization, as we can see the expansion especially in the northern part of the city [Figure 4].
Last, this article opens the way for a future study that searches deeper for the factors that influenced the urban expansion in small and medium-sized cities but also the problems that emerged in terms of spatial planning and urban landscape.

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