

## LAND USE AND LAND COVER DYNAMICS IN THE PERIURBAN AREA OF AN INDUSTRIALIZED EAST-EUROPEAN CITY AN OVERVIEW OF THE LAST 100 YEARS

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**Abstract:** Landscape is in continuous change since the human society started to exploit it. The driving forces for land-use and land-cover (LULC) changes might be considered divers, but one of the main cause is the natural resources accessibility. Oil resources shaped, indirectly, the landscape worldwide, being a direct driving force for LULC change patterns for oil oriented cities. Diachronic analysis of LULC dynamics in such an urban settlement shows how the urban and periurban landscape has changed from the beginning of oil extraction and processing activities to present days. Ploiești city, from Romania is a traditional oil center from Eastern Europe that faced a continuous evolution, under different planning policies, due to its oil based industrial activities. The study focused on the city's urban and periurban area and covered a timeframe of 105 years of landscape changes, divided in three periods (*The Royal Period*, *The Socialist Period* and *The Post-communist Transition*) characterized by different political ideologies. The study emphasized the fact that oil oriented cities are more independent of political planning, the resources being the main driving force for landscape patterns.

**Keywords:** oil oriented city, land-use and land-cover, periurban area, Eastern Europe

### 1. INTRODUCTION

The potential of human society to alter the landscape is growing, and the landscape is becoming increasingly more diverse each day (Pinto-Correia & Kristensen 2013). From a local to a global scale, landscapes are an expression of the interaction between many factors (Breuste et al., 2013) – factors that have become of great interest both to the scientific community and to international organizations that analyse land-use and land-cover (LULC) changes. LULC patterns often indicate the development rate of a particular area (Grădinaru et al., 2015). These patterns are useful for studies focusing on territorial

planning strategies (Roose et al., 2013), environmental impact assessment (Robinson 2011; Mölders 2012) and climate change mitigation, or for highlighting the potential of future land use conflicts (Ioja et al., 2013).

In recent decades, researchers studying LULC aimed to develop a methodology to help assess the impact of LULC changes on the landscape (Haase et al., 2007) and human quality of life (Wu 2013). At the same time, another aim of these studies was to predict future change patterns (Aguilera et al. 2011) in order to establish ideal evolution models (Rutherford et al., 2008), thus avoiding future land use conflicts (Tudor et al., 2014). In terms of human settlements, studies have highlighted that the causes

of LULC changes are generally related to urbanisation, an increase in population, and changes in patterns of human consumption, but this topic is very pervasive and the major causes are not always the obvious ones. On a local scale, LULC changes are influenced by elements such as planning policies (Trutnev et al., 2004), socioeconomic conditions, the natural background (Hersperger & Bürgi 2009), infrastructure or cultural and historical factors (Dobos et al., 2014). Moreover, the presence of a particular natural resource near a human settlement can be a significant driver of LULC changes (Sleeter et al., 2012).

The dynamic of LULC changes is not without its consequences, especially in terms of areas located at the periphery or the proximity of urban areas (Corpade et al., 2014). The main drawbacks highlighted by researchers and the international community have focused on habitat fragmentation and loss of biodiversity (Robinson 2011; EEA 2011), abandonment or loss of fertile agricultural land (Grădinaru et al., 2013) and loss of traditional landscapes. However, LULC changes can generate a positive impact on the local economy, boosting the investments of private stakeholders in the region (He et al., 2013).

In Europe, we are witnessing a conversion towards a post-industrial era (Bell 1976), but the former industrial landscapes still exist in most of the cities. As industrial activities were sustained by natural resources such as oil, coal and minerals, it has become increasingly important to analyse the role of these resources in shaping LULC changes throughout history and to determine whether they are still an important driving force today.

The presence of oil resources may drive significant landscape changes. Baynard (2011) and Baynard et al., (2012) analysed the impact of oil exploration and production activities on the natural landscapes of Venezuela and Ecuador, emphasizing that oil extraction, processing and transportation play an important role in surface alteration, causing damage to agricultural land. The study conducted by McCracken and Foster (2014) showed that forest disturbance generated by the construction of access roads and infrastructure relating to oil extraction and processing activities had a negative effect on Ecuador's lowland rainforests. In China, Bi et al (2011) focused on landscape fragmentation driven by the construction of access roads and oil wells, while Ottinger et al. (2013) referred to the prosperous oil industry as being a driver of economic development and urban growth. The study conducted by Tang et al., (2008) is one of the few studies that incorporated in the analysis the impact of differing socio-political

contexts on the urbanisation process driven by the oil industry.

Most studies have analysed the changes over a rather short period of time (25 years or fewer) and have focused either on the oil fields or on the urban areas from a secondary perspective; in both cases, two different situations have been compared. In this paper we correlated two driving forces such as the availability of oil resource and the different political regimes with the present structure of the LULC of an East-European city and its periurban area. The 100 years of recorded changes could offer an overall conclusion regarding the structure and functionality of the urban areas in the former communist countries.

**Oil-oriented cities** experience higher LULC changes and urbanisation rates than non-oil-based cities, as a result of economic prosperity. Oil-oriented cities are industrial cities that developed as a result of oil extraction and processing activities. In this type of city, the urban expansion eventually '*spills over*' into the industrial sites located at the periphery or in the urban fringe, changing the landscapes and the environment. Worldwide, oil-oriented cities are generally prosperous, with high rates of employment and wages that assure a high standard of living, but at the same time can face a variety of social and environmental problems. Planning in oil-oriented cities faced a new paradigm from the start of the oil extraction industry and its associated processing activities, and the LULC changes became more dynamic (Obeng-Odoom 2014). The economic boost that such an industry provides for a city must be oriented towards a reconversion strategy for the point when the oil resources have been exhausted. In the next part of the paper, we will highlight how oil influenced the LULC changes in Ploiești.

The oil industry in Romania started to develop in the late 19<sup>th</sup> century and, at that time; Romania was one of the main producers of oil-based products worldwide. Meanwhile, the discovery of other important oil deposits across the globe reduced the importance of Romanian oil deposits. The traditional oil exploitation regions are based in the hilly region at the edge of the Carpathian Mountains. The core of the oil extraction and processing activities is located in Prahova County and the main industrial activities are located in Ploiești, a city 60 km north of Bucharest. Over the last 100 years, Ploiești has developed very rapidly compared with other similar cities in Romania. The city remained an important site of urban growth even in the post-socialist period, when many former industrial cities of Eastern Europe could not compete with the market economy challenges, and faced bankruptcy and decline (Hirt & Stanilov 2009; Stanilov et al., 2007).

Analysis of LULC change patterns for different historical periods represents a retrospective landscape monitoring technique (Kienast 1993). This type of analysis can serve as an instrument in periurban planning, being essential in creating landscape evolution scenarios (Pătru-Stupariu et al., 2011). The evaluation of LULC dynamics is mainly achieved by analysis of quantitative and statistical data (Haase et al., 2007). When analysing the structure and function of an urban system, the relationship between such data and the change pattern and its processes must be examined (Tang et al., 2008).

The aim of this paper was to determine how the presence of oil as a natural resource was a key factor that influenced specific LULC changes and associated processes in Ploiești and its periurban area. Therefore, the main objectives were: a) to determine the spatial pattern of LULC changes from the beginning of the oil extraction industry and its associated processing activities between 1900 and 2005, and b) to correlate the magnitude of the changes with each event in the history of oil exploitation and processing.

## 2. THE PLOIEȘTI PERIURBAN AREA: AN AREA DEVELOPED UNDER THE INFLUENCE OF OIL RESOURCES

The Ploiești periurban area (PPA) is located in the south-eastern part of Romania, in a plain area with almost no geomorphologic restriction for the development of built-up areas, biasing a radial concentric shape (Fig. 1). It was chosen as a case study because of its historical importance in the European oil industry and because it represented a good example of an area that has evolved through different political regimes and planning strategies. The LULC dynamics in this area reflects a general picture of how an urban area's evolution is sustained mainly by an economic activity and how planning policies can shape properly or not the landscape of a city and its periurban area.

In 2011, 25.4% of the working population in the region was exclusively employed in the oil industry sector (INS 2011), without the employees working in relating fields such as transportation, suppliers or research. The PPA is one of the most developed areas in Romania consisted of eight Local Administrative Units (LAU2) and the city Ploiești in the centre, where 79% of the studied area's population lives in. Beside the normal agricultural profile, the eight rural settlements have several industrial units located within the settlements (Zachi et al. 2004). Today, most of the land cover is for agricultural purposes, representing more than 70% of the study area.

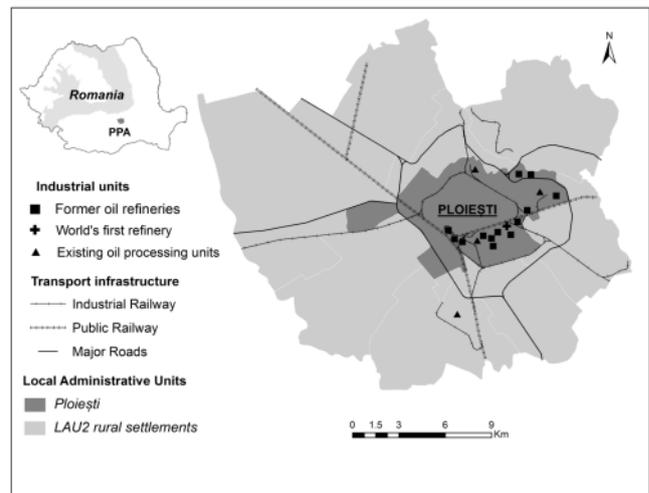


Figure 1 Study area

The main event in history that deeply changed the urban landscape and the economic profile of Ploiești was the Mines Regulation Act, approved in 1895 (Ivanuș et al., 2004), which gave any person the right to exploit any underground oil resource without the state exerting any property rights over it. During that period, the Romanian authorities encouraged foreign investment as the local businessmen did not have sufficient capital to sustain oil extraction costs. The investors, mostly Germans initially, started to purchase large plots of land from peasants and local wealthy people. The first factories to process oil were built on such plots, located at that time on the outskirts of the city (Fig. 1). Consequently, in this period, Ploiești's suburban landscape was industrialized and former rural settlements located near the city became new urban districts.

In the communist years, other oil-based and non-oil-based industrial sectors were developed that were more suited to female labourers (including one garment factory). The factories were mainly built within the city. The oil-related industrial units were enlarged and refurbished.

After 1990, the Romanian industry faced decline; oil industry activity regressed slightly but survived over the transition years. After 1990, the laws regarding unique property, restrictions on urban housing, and the expansion of spaces within built-up areas had been abrogated. Thus, the expansion of the cities became somewhat chaotic. Several cities that had developed during the socialist period faced serious economic imbalances, as was the case in other former communist countries. The transition to a different political system and market economy led to new kinds of urban transformation – suburbanisation and urban sprawl – all across Romania (Suditu et al., 2010; Ioja et al., 2011; Gavrilidis et al., 2011). The new economic system that emerged following the post-socialist transition led to the

development of different entrepreneurial activities in most of the cities, as was the case with Ploiești. Table 1 highlights the oil exploitation and processing history and development of Ploiești.

Table 1 Events considered to be turning points in the history of Ploiești.

Period	Event
1600–1850	-18 <sup>th</sup> century: the city becomes the administrative centre of the region -1800–1850: the city expands from 190 ha to 520 ha
1850–1918	-1856: the building of the world’s first refinery – ‘The Gas Factory’ -1866: the construction of the railway Bucharest–Ploiești–Predeal -1913: 13 refineries are built around Ploiești (Ivanuş et al., 2004)
1918–1945	-1918: area of 1927 ha and 45107 inhabitants 1 <sup>st</sup> December 1918: Transylvania province becomes part of Romania, increasing the status of Ploiești as one of the main communication routes between Bucharest and Transylvania -March 1940: ‘oil agreement’ between Romania and Germany – Ploiești becomes the main fuel supplier to the German army -1 <sup>st</sup> August 1943: the American forces bomb eight refineries and parts of residential areas in the ‘Tidal Wave’ operation
1945–1990	-1960–1965: construction of the first major ‘worker districts’ in the western and northern part, consisting of residential buildings with 4 and 10 floors – people from the nearby rural areas migrate to the city -1966–1977: 30 industrial sites secure 60% of the industrial production from Prahova County -1989: end of the communist regime
After 1990	-1991: the Romanian Oil Company ‘PETROM’ is established -1998: ‘Teleajen’ Refinery was purchased by Lukoil Company, which started to modernise it -1999: ‘Vega’ Refinery was purchased by Rompetrol Company 2004: OMV Group buys the Romanian Oil Company and the ‘Petrobrazii’ Refinery 2010: urban area reaching 5820 ha

### 3. DATA AND METHODS

#### 3.1. Data extraction and classification

The analysis took into account the information from four maps that presented data relating to the PPA from the beginning of the 20<sup>th</sup> century to the present (Table 2). Given the different sources, all the maps were digitized and re-projected by means of Romanian coordinate system (Double Stereographic 70) using ArcGIS 10 software.

The entire period was divided into successive historical frameworks, corresponding to different political regimes: (a) *The Royal Period, 1900–1945*; (b) *The Socialist Period, 1945–1990*; and (c) *The Post-communist Transition, 1990–2005*. These three time frameworks were chosen to highlight the influence of different planning strategies on the political regimes. *The Royal Period* was incorporated into the **T1-T2** framework, where T1 represented the year 1900 and T2 represented the year 1950; *The Socialist Period* was incorporated into the **T2-T3** framework, where T3 represented the year 1985; and *The Post-communist Transition* was incorporated into the **T3-T4** framework, where T4 represented the year 2005.

The LULC were grouped into six classes based on the representative human activities for the area and cartographic data. The **agricultural** class consisted mostly of arable land but also includes pastures and vacant land on account of their small area coverage. The **residential & commercial** class included urban and rural built-up areas within the PPA. Land occupied by industrial buildings and the adjacent open-space was classified as the **industrial** class. In addition, a specific class was represented by the area occupied by **greenhouses**. The **forest** class was created in line with the Romanian National Forest Code, which defined ‘forest’ as a plot of land, outside the urban built-up zone, with an area wider than 0.25 ha (Government of Romania 2008).

Being part of the local land use tradition, in the northern part of the study area, the orchard and vineyard land uses were grouped in one class termed **permanent crops**. The land use polygon datasets were converted to raster files, using a 25×25 m resolution, based on the original scale of the map (Tobler 1987).

#### 3.2. LULC pattern analysis

The LULC data were analysed in two ways: graphical spatial representation and processing of quantitative data (Fig. 2). Graphical spatial representations were created using binary change maps, by highlighting those areas that underwent changes from one period to another, and using trajectory maps, representing inter-class changes. Quantitative data relating to LULC surfaces were processed using the following landscape change indices:

(a) *Binary change index*. This represented the overall change in magnitude (Pătru-Stupariu et al. 2011), ranging from 0 to 1, with lower values indicating higher changes.

(b) *Cramér’s V index of association  $\phi_c$* . This calculation was based on a transition matrix (Agresti 2002), where  $\phi_c=0$  represented no association and  $\phi_c=1$  represented perfect association. This index is

Table 2 Cartographic resources` characteristics and source

Time	Map	Year	Scale	Source
T1	Romanian Maps under Lambert-Cholesky projection	1900	1:20 000	Both maps are open-source resources, available for download at geo-spatial.org community website <a href="http://earth.unibuc.ro">http://earth.unibuc.ro</a>
T2	Soviet Maps	1945	1: 50 000	
T3	Romania Topographic Map	1985	1: 25 000	Provided by the University of Bucharest, Faculty of Geography in digital format
T4	Ortophotomaps	2005	1:5 000	Available on the INIS Inspire Geoportal through National Agency of Cadastre and Land Registration

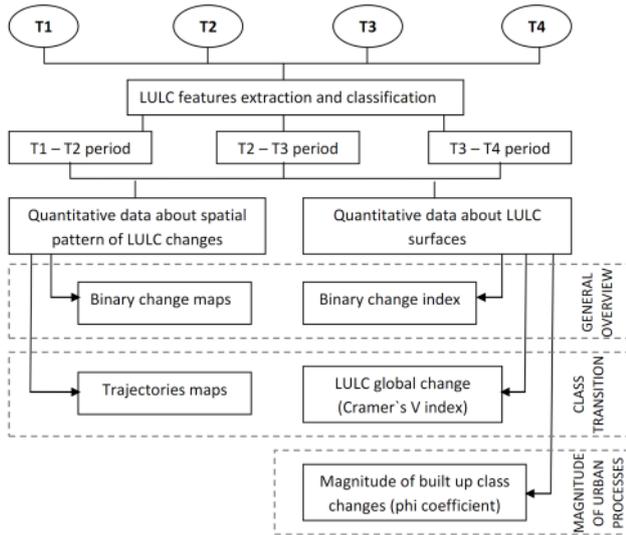


Figure 2 Methodology for LULC changes analysis

used as a similarity measure in landscape spatio-temporal analysis (Van Eetvelde & Kayhko 2009).

(c) *Phi coefficient* of association for binary variables. This was used for measuring the magnitude of change driven by urban processes. The phi coefficient ranged between 0 and 1, where 0 represented no relationship and a value near 1 indicated an almost perfect relationship (i.e. major changes, respectively no changes between periods). The coefficient was calculated only for **industrial** and **residential & commercial** land-use classes.

The selected methods show not only the 'from'

and 'to' data but also the quantity and magnitude of change within each class.

#### 4. RESULTS

The overall spatial pattern of the LULC changes began as large-scale transformations throughout the periurban area and successively shifted to changes that took place on smaller and more dispersed plots of land (Fig. 3).

The trajectory maps showed that the main changes occurred within the *industrial* and *agricultural* classes. Here, the  $\phi_c$  value indicated that the overall class changes were the smallest throughout the entire century. A greater magnitude of changes compared with the previous period was recorded for both *industrial* and *residential & commercial* areas (Fig 4), reaching a change rate of up to 20%. The stagnation in oil processing and extraction led to a more fragmented LULC pattern, highlighting a process that would expand significantly over time.

The most dynamic time period regarding LULC changes was the T1-T2, which revealed important changes in local activities and the class with the highest rate of transition. During the T1-T2 period, the urban core almost tripled its size and the entire periurban area was characterized by deforestation due to agricultural intensification (Fig. 4).

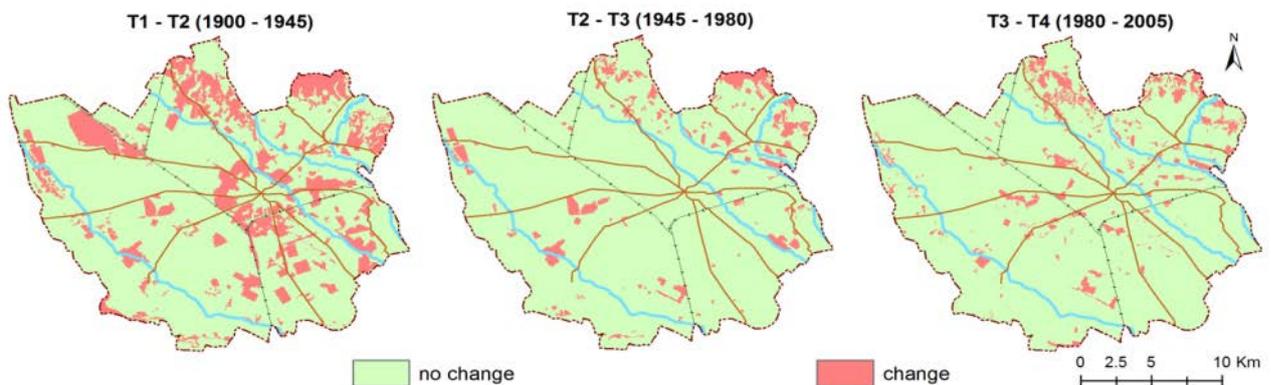


Figure 3 Binary maps of LULC changes in PPA during 1900-2005

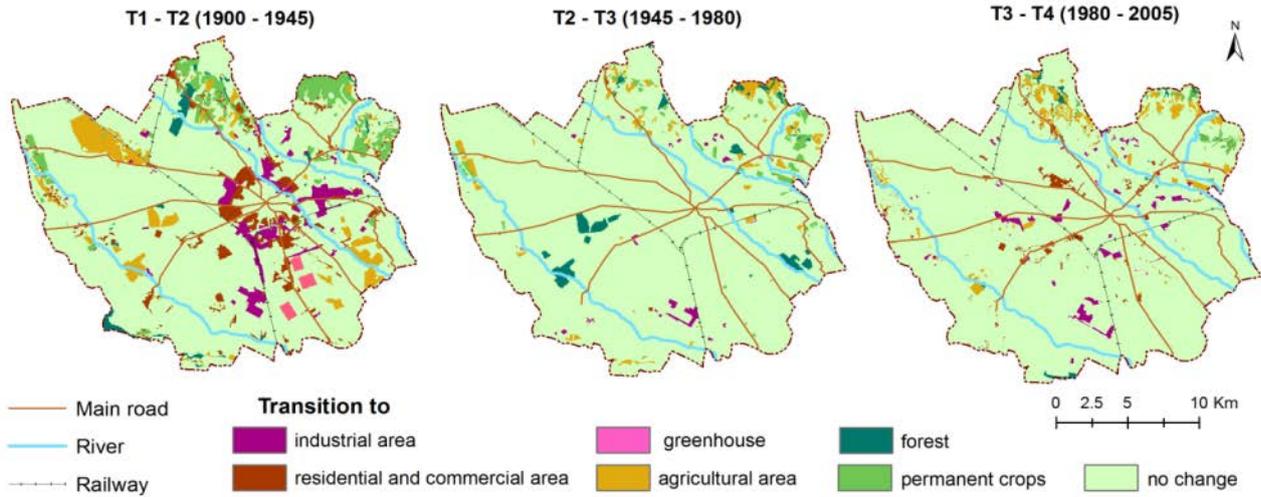


Figure 4 Transition maps of LULC changes in PPA during 1900-2005

Besides arable land expansion, large areas located in the north were transformed into vineyards and orchard plantations. Urban growth encompassed the most significant changes, with built-up areas developing in the suburbs as a concentric ring around the city centre. Phi coefficient values indicated that although the total surface area that evolved into residential built-up districts was higher than the area that evolved into industrial districts, the magnitude of change within the class was much higher for industrial areas, marking the start of an industrial

future based on oil resources. The results were further corroborated by the finding that the highest rate of change occurred within the industrial class – beyond 20% (Fig. 5).

The patterns that dominated the T2-T3 period were represented by changes in the *agricultural* class, as determined by crop rotation (Figs 3 and 5). The  $\phi_c$  value represents clear evidence of a reduction in the LULC dynamic of the LULC compared with the previous period (Table 3).

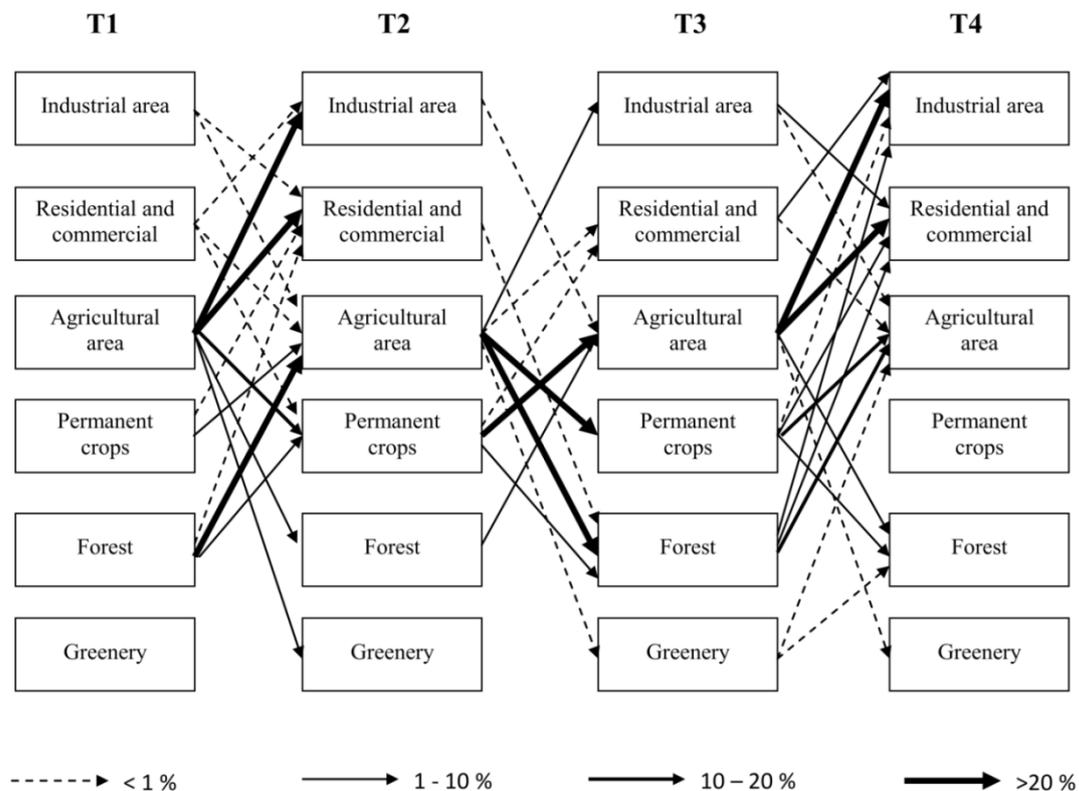


Figure 5 Trajectories of LULC changes in PPA during 1900-2005

Table 3 Values of change indexes for each analyzed period

Index	Period		
	T1-T2	T2-T3	T3-T4
Binary Change Index (BCI)	0.59	0.87	0.86
Cramer's V index of association ( $\varphi_c$ )	0.38	0.79	0.74
Phi coefficient of association – industrial area	0.64	0.98	0.91
Phi coefficient of association – residential and commercial area	0.21	0.93	0.85

Urban expansion was marked by a standstill, with almost no expansion of *residential* & *commercial* units and a slight increase in industrial units (Fig. 6). Previously deforested plots located in the eastern and western part of Ploiești returned to their forestry land use (Fig. 3).

Binary and trajectory maps for the T3-T4 period indicated a new LULC pattern, namely changes in the size of the plots, with a pronounced tendency towards fragmentation. Crop rotation is still practised in the northern region (Figs 3 and 4), and landscape change indices show a slight increase in the built-up LULC classes (Table 3 and Fig 6).

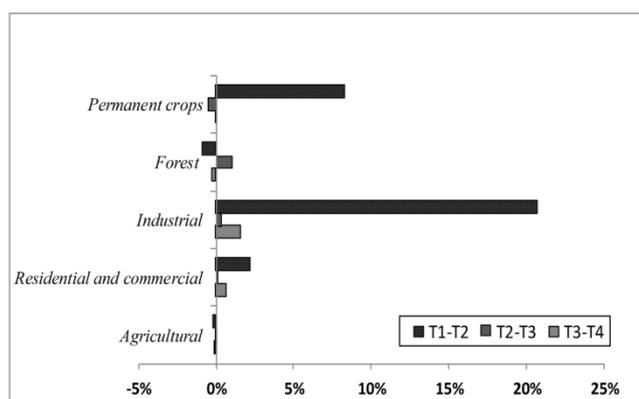


Figure 6 Growth rates for each LULC class

## 5. DISCUSSION

### 5.1. LULC analysis of dynamics

The major findings of the paper confirm that the presence of oil resources influenced the LULC patterns in the Ploiești periurban area. These patterns were influenced in an important way by the planning policies of each period. The beginning of the industrial activities was emphasized by the major expansion of built-up areas, the slight increase in agricultural land, and the reduction in forest areas.

Binary change maps and binary change index indicated that the T1-T2 transition period was the most dynamic of all the periods analysed owing to the enthusiasm for construction driven by the discovery of oil deposits. The high rate of urban growth resulting from economic development was similar to the cases reported by Ottinger et al., (2013) and Tang et al.,

(2008), who classified the process as an industry-related urbanisation. Tremendous changes took place at the periphery of Ploiești as well as in the northern hilly area. Combining the results with the information provided in table 1, it is evident that this is the period when oil exploitation and processing activities blossomed. The high number of immigrants who arrived from all over the country – attracted by the oil industry jobs – led to an increase in food demand and an intensification of the agricultural sector.

*The Socialist Period*, T2-T3, records the shift to the communist territorial planning system. The strategy of the communist political regime was to prevent the PPA from becoming a mono-industrial area through investing in medium and small non-oil-based factories in the urban core, and through agriculture intensification in the periurban area. As the city itself was already industrialized, the regime focused on the modernization of the existing infrastructure rather than on its expansion (Ivanuş et al., 2004). These planning and political strategies had an important influence over the LULC patterns within the PPA. As a result, the villages from the periurban area retained their rural features, conferring on the region the particularity of having a homogeneous industrial core surrounded by a rural ring. Maintaining the rural profile of the periurban area was easily achieved through centralized agricultural management and state ownership over the land.

At the beginning of our study we predicted that *The Socialist Period* would record major LULC changes, represented by an increase in built-up areas in order to achieve the socialist ideals of industrialisation and prosperity. However, the case of Ploiești proved different to that of other Romanian (Ianoş 2004) or Eastern European cities (Hirt and Stanilov 2009) that became industrialized under communism.

*The Post-communist Transition*, T3-T4, records the LULC changes following a new political shift. While other industrial regions that developed exclusively in the socialist period faced decay after 1990, leading to social imbalance and high unemployment rates, the industrial activities from PPA continued. The economic profile of the city was partially sustained by massive privatization of the oil industry, initiated in 1998 (Table 1) and by the development of the service sector. We observed that,

during the ‘*non-communist*’ regimes (T1-T2 and T3-T4), the land occupied by industry and built-up areas increased (Fig. 4). In the Post-communist Transition, the *non-oil*-based factories were no longer profitable and their privatization led to bankruptcy. They ceased to operate and were later divided into smaller properties.

As the results show, the compact rural ring that surrounded the urban core was divided into smaller plots by different types of built-up areas. A similar situation was reported by Tang et al., (2008), who observed a tendency towards a more fragmented pattern of the impervious surfaces over time, in their 24-year landscape analysis of two oil-oriented cities.

Oil-linked activities led to significant changes in LULC patterns in the PPA. Similar results from other studies analysing the impact of oil infrastructure on urban and non-urban landscapes showed that the existence of oil resources in a region leads to important LULC changes owing to the economic value of oil and the worldwide demand for it.

## 5.2. Implications of using historical maps and landscape indices

LULC analysis based on historical maps may present both advantages and some difficulties. Transforming the map into LULC categories facilitates analysis and allows a comparison between time periods, but data processing involves a loss of information due to spatial and thematic aggregation of the original maps (Pătru-Stupariu et al., 2011, Dobos et al., 2014). Moreover, a unified legend is sometimes difficult to obtain when the objects are mapped differently. An object may be represented on more recent maps, e.g. commercial areas; while on older maps it may be mapped differently or included in a ‘built-up’ category. When using binary change and trajectory maps, the graphical data must be correlated with information regarding drivers of change in order to explain the phenomena that occurs within the analysed area. When using coefficients of association in landscape analysis, special attention must be paid to the structure of the analysed area. Even though they reflect the magnitude of change for a specific land use class, the values can be biased by the proportion of that class from the total study area. It is essential to understand the relationship between the impact of a class change and its spatial extension.

## 6. CONCLUSIONS

Oil-oriented cities are dynamic urban settlements that attract populations in search of prosperity and wealth. The level of appeal is reflected

in LULC changes that shape a territory in order to fit its oil-based profile. This type of approach can cause an unhealthy interdependence between a city and its resources, and can lead to serious social, economic and planning imbalances if not properly managed. It is understandable that the oil-oriented city should have a particular dynamics of LULC patterns caused by the oil resource itself but at the same time the economic boost that such an important energetic resource gives to a city should be used in order to anticipate the shift to a new economic profile after the twilight of the oil age. Planning policies should consider the type and level of resources that are available within defined areas, and the activities that derive from the existence of such resources. Most natural resources are exhaustible. Thus, new LULC patterns can be predicted by taking into account the point at which a finite resource will be depleted, thereby avoiding derelict land or brownfield sites in the future.

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