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REGIONAL PATTERNS OF THE POPULATION AGEING PROCESS IN ROMANIA (1992–2021)

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Key-words: demographic ageing, average age, typology, determining factors, regional disparities, Romania.

Abstract. Population ageing has become an issue of maximum interest in developed countries. Romania is facing the acceleration of this process in the context of the post-1990 decline in fertility and the post-2000 massive emigration after 2000. The main objective is to outline regional and local disparities, starting from the hypothesis that they are due to the differentiated actions of various factors which can stimulate or slow down demographic ageing. The methodology used proposes a descriptive, typological perspective, coupled with a multivariate one. Several regional patterns of evolution, induced by specific ways of adapting to social, economic and political transition, are thus highlighted. The fast expansion in urban areas and the relative rejuvenation of the population in metropolitan areas, which expresses a population transfer induced by changes in people's lifestyle, relocation of economic activities and increased mobility, generated much interest. At the same time, the prevalence of agricultural activities and the decline of mining shape the context of an unprecedented ageing process in areas threatened by depopulation. The paper concludes that the evolution of the ageing process is similar to that of neighbouring countries and that there are strong rural-urban disparities.

1. INTRODUCTION

Sharp demographic ageing used to be a predominant trend in 20th century Europe, while in the 21st century it has all the prerequisites to worsen (Grundy and Murphy, 2018). Considered one of the most typical features of the second demographic transition (van de Kaa, 1987), this process is a consequence of the changes induced by demographic transition on fertility and death rate patterns, as well as of the impact of population mobility, especially international migration (Káčerová *et al.*, 2014; Naumann and Hess, 2021). It is a huge challenge for social protection systems due to the increase in the dependency rate and the manifestation of an acute labour shortage, and questions the welfare state itself (Galasso and Profeta, 2007). Identifying the causes, evolution patterns and implications of demographic ageing becomes the priority in order to find adaptation solutions (Davies and James, 2011). Resilience is becoming an increasingly important concept in public health, shifting social policies from limiting ageing to actively integrating it through measures meant to increase the quality of life of the elderly (Cosco *et al.*, 2017). The origin of this process is usually sought in past fertility cycles (Reher, 2015) and the trends that define it have been anticipated for a long time (Sauvy, 1948; Laslett, 1987). The evidence of the manifestation of various spatial differentiations, both in the urban and rural environment, underlines the importance of several local and regional factors in explaining the evolution patterns of the structure by age groups (Kashnitsky *et al.*, 2021). Human capital, education level, health status and life expectancy may implicitly lead to the manifestation of a profoundly differentiated dynamics at the territorial level, along with the overall demographic evolution (Balachandran, 2020).

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In Romania, the evolution of this process is characterized by the specificities of the demographic transition, and, later on, disrupted by the demographic policy of the communist regime, which occurred prior to 1989. The demographic shock felt after the collapse of this regime quickly changed the population structure by age groups, while the massive post-2000 emigration (initially for labour reasons, and subsequently for lifestyle reasons) triggered an increase in the share of the elderly population (Gheţău, 2007). The combination between the decline in fertility, and increased life expectancy at birth and the massive emigration of the young adult population, responsible for the drastic decrease in the population (by more than 4 million inhabitants between 1992 and 2021) make up the main causes of the worsening of the ageing process, which is practically impossible to avoid in the medium term (Bodogai and Cutler, 2014). Public policies are poorly prepared to deal with increasing social demands, both in the rural environment, which is almost completely devoid of means (Kulcsár and Brădăţan, 2014), and in the urban one, strongly perturbed by the three decades of transition (Ivan *et al.*, 2020).

Geographical research can also contribute to a deeper understanding of the forms of manifestation of this process which, through its specificities, pays special attention to spatial diffusion, territorial differentiation and the manifestation of regional patterns of evolution. Anchored in the interdisciplinary field of gerontology, geographical studies, predominantly descriptive for the longest time, focused on analysing the territorial distribution of the elderly population and, sometimes, the correlations with environmental or well-being issues. They have evolved towards the identification of spatial patterns since the final part of the past century (Rowles, 1986; Sanderson, Scherbow, 2016). At the same time, ideas, concepts and approach models used in gerontology have been assimilated, reinforcing the need for a holistic conceptualization in order to identify the historical bases of this process (Warnes, 1990). The possibility of manipulating detailed databases, along with the use of computer processing means favoured the transition from a descriptive approach to an analytical one (Harper and Laws, 1995), thus developing a genuine "geography of ageing" (Skinner *et al.*, 2015). Partly overlapping traditional geographical subjects (population geography, geography of health, social geography), also named "geographical gerontology", it has increasingly focused on the relationships between the elderly people and the places they frequent (Cutchin, 2009). Three main themes of interest have been settled since 30 years ago: the trends in the spatial evolution of the ageing process, frequently correlated with the mobility of the elderly; the territorial disparities induced by the access to health and social assistance services; the factors which influence the quality of life of the elderly in connection with the quality of the environment. Closely linked to the public policies of "active ageing" and the stimulation of age-friendly communities (Golant, 2014), specialized geographical studies often resort to the principles of sustainable development or of inclusive governance (Han *et al.*, 2021). Along with population growth, international migration and rapid urbanization, ageing is seen as one of the global "megatrends" which are shaping this century (Messerli *et al.*, 2019). Consequently, it is necessary to profoundly revise how society works from a spatial perspective (MacCarthy, 2022), although, as many authors underline, governments are barely aware of the process of demographic ageing and do not have the forethought required to limit its effects (Thumerelle, 2000).

In this disciplinary context, the present study proposes a chrono-spatial analysis of the post-communism evolution of the ageing process of the Romanian population. The beginning of the analysis period is marked by the completion of the demographic transition, postponed by the pro-natalist policy of the Ceaușescu regime, but accelerated by the post-1990 crisis (Rotariu, 2014). Rapidly imposed, especially given the massive emigration of the young population, and a victim of the post-communist restructuring of productive activities, this process has also been sped up by the increase in life expectancy after a long period of stagnation, particularly after the year 2000 (Muntele *et al.*, 2020). The evolution trends of the ageing process of the Romanian population are similar to those noticed in other countries in the central and eastern part of the continent, recording similar gaps, in comparison to western countries, in terms of the public policies on active ageing (Olivera, 2020), the reversal of the international migration flows which could help mitigate the share of the elderly population (Długosz and Kurek, 2006; Lewandowska-Gwarda and Antczak, 2020), or the incomplete epidemiological transition (Kinsella, 2000).

The specific eastern European context, for which Romania is a prime example, is a dangerous combination between the three acknowledged forms of ageing: at the bottom (caused by fertility decline), median (induced by the significant emigration of the young adult population) and top (triggered by the increase in life expectancy) (Sardon and Calot, 1999). A combination also specific to southern Europe in the past (Marcaletti *et al.*, 2020), it will disrupt demographic balance in the long term. By contrast, the west of the continent has experienced a succession between bottom and top ageing, with a significant time lag (Naumann and Hess, 2021). The aforementioned combination coincided with profound political, economic and social transformations generated by the dissolution of the communist regimes. The elderly generation is often seen as the main loser of the transition to the market economy (Botev, 2012). What is also typical of the Romanian (and eastern-European) pattern, apart from the accelerated ageing rate, is its generalized character, affecting both the rural and urban environment. During the past decades, this has significantly drawn the attention of specialists in the social sciences, who have emphasized its effects on the public social assistance services, poorly prepared to deal with it (Asandului, 2013; Bodogai and Cutler, 2014). The specificity of Romania within the European context has also often been approached in order to identify solutions for the implementation of certain community policies (Gabor *et al.*, 2022). Other studies have focussed on the determining factors, such as international migration (Nemenyi, 2011), the mutations caused by the deepening of the social and economic gaps (Jemna and David, 2021) or the ability of the territorial structures to adapt to this process (Istrate *et al.*, 2015).

The analysis of the previously published papers pointed out a shortage of studies at the national and regional scale and the fact that they only deal with general trends. For this reason, our study opted for a detailed analysis, carried out at the level of the 3,181 basic administrative units in Romania (communes, towns and municipalities). The main objective is to identify the manifestation of some regional evolution patterns of the ageing process, in correlation with a series of socio-economic, cultural and geographical factors. In this context, the key issues that arise are the following:

Is the generalization of the demographic ageing process in Romania a pertinent subject?

Do the chronology of the manifestation and the development speed of this process produce regional gaps?

Can the differential evolution of the demographic transition explain the features of the regional patterns of evolution?

What role did the strong shrinking of the urban population and the building-up of metropolitan agglomerations play in the manifestation of divergent trends in the ageing process?

Is there, locally or regionally, a manifestation of a resistance to this process? What are the factors that can explain these forms of adaptation?

The working hypothesis that emerges from these issues is the following: leaving aside the general trends outlined by various papers, when analysing the ageing process in Romania significant territorial disparities (generated by the differentiated action of the factors that favour or limit it) can be noticed.

In order to test this hypothesis, the present study takes a double approach: a descriptive analysis, aimed at identifying some typologies of the evolution of the ageing process, using the structure by age groups and the average age as variables; a multivariate analysis of the explanatory role of a series of demographic, socio-economic and geographical variables, the average age being the dependent variable.

We believe that this approach helps with understanding the demographic crisis Romania is going through (the population dropped from 22.8 million in 1992 to 19 million in 2021, one of the most serious declines in Europe) and clarifies the particularities of the aging process for each of the four moments analysed.

2. MATERIALS AND METHODS

The information needed for the two analyses was collected from the databases of the National Institute of Statistics. Two distinct sets of information were created: one relating to the population structure by age groups, gender combined; the other one containing derived information illustrative of variables with an explanatory role in the evolution of the ageing process.

For the descriptive analysis, the share of each age group (*Px*) in the total population *Pt* (*Px/Pt*100*) was calculated for each of the four censuses conducted in Romania after 1990 (1992, 2002, 2011 and 2021). The four percentage datasets derived were then subjected to a hierarchical agglomerative clustering (AHC) typological analysis in the XLSTAT software (Addinsoft, v. 2015). Using Euclidian distance and grouping statistical units by their degree of similarity (Ward's method of clustering), the typology aimed to keep the values of intra-class dispersion coefficients at a minimal level compared to inter-class dispersion coefficients, thus ensuring class homogeneity. Eight classes with a distinct profile were selected and then mapped with the help of the Adobe Illustrator CS12 program. The class profiles were compiled in Excel. For comparison purposes, the average profile was also illustrated.

A total of 14 explanatory variables were selected for the factorial analysis. The average age was chosen as a dependent variable, after previously testing its correlation with the ageing index, more dependent on the share of extreme age groups. For all four time series, the correlation coefficient of the two indicators exceeded 0.9. The average age was preferred because it expresses the ageing phenomenon in a more synthetic manner, taking into account all age groups. It was calculated as follows: $X = \frac{\sum(x+0.5)Px}{\sum Px}$, where X represents the average age, Px is the number of people of age x and 0.5 is the average equivalent of the variation of the deviations from the exact date of turning a certain age.

The description of the explanatory variables, the source of the information they were based on and how the derived values were standardized appear in Table 1. Four of these variables were regarded as constant for the whole analysis period, while the others were calculated for each time series. The choice of these variables is consistent with various studies which analyse the main factors that trigger the process of structural ageing (the population's demographic history - Preston *et al.*, 1989; fertility, mortality and migration - Hoff, 2011; mortality improvement, especially in low-fertility countries – Murphy, 2017; geographical drivers - McCann, 2017; fertility decline and net migration - Smailes *et al.*, 2019; per capita GNI, urbanization rate and life expectancy - Wang, 2020, etc.).

Table 1

Variables used in the factorial analysis – description and source of information

<table>
<tr><th>Type of variable</th><th>Variable</th><th>Acronym</th><th>Description</th><th>Information source</th><th>Standardization</th></tr>
<tr><td>Dependent variable</td><td>Ageing Index</td><td>AI</td><td>Ratio between the population aged 65 and the population aged 0−14</td><td>Romania's population censuses of 1992, 2002, 2011 and 2022</td><td rowspan="4">Z scores, outliers removed</td></tr>
<tr><td rowspan="3">Explanatory variables</td><td>Bottom ageing</td><td>BA</td><td>Ratio between the average birth rate of the last intercensal period and that of the penultimate period</td><td>Tempo Online database of the INS (1966-2021), www.insse.ro</td></tr>
<tr><td>Median ageing</td><td>MA</td><td>Average migratory balance in the last intercensal periods</td><td>Tempo Online database of the INS (1966-2021), www.insse.ro</td></tr>
<tr><td>Top ageing</td><td>TA</td><td>Ratio between the 50−64 and +65 age groups</td><td>Romania's population censuses of 1992, 2002, 2011 and 2022</td></tr>
</table>

Table 1 (continued)

Oldest old	OO	Share of +80-year-old population in the total of +65-year-olds	Romania's population censuses of 1992, 2002, 2011 and 2022	
Average altitude of habitat	ALT	Considered for main localities	Topographic map 1:100 000, Military Topographic Directorate https://www.geomil.ro/Descarcare	
Habitat fragmentation	FS	Ratio between population and number of localities	Romania's population censuses of 1992, 2002, 2011 and 2022	
Position in relation to main cities	LMC	Distance in km on the shortest route to cities with more than 50,000 inhabitants	"România. Mare atlas rutier" (Romania. Great Road Atlas) 1:200,000, AGC Busman SRL, 2011	
Access to major transportation network	AMT	Factor scores by importance of transport means. Maximum value (1) granted for railways and European roads; minimum value granted for local roads.	"România. Mare atlas rutier" (Romania. Great Road Atlas) 1:200,000, AGC Busman SRL, 2011	Factor score
Shared of population employed in agriculture	PEA	Share of the employed active population	Romania's population censuses of 1992, 2002, 2011 and 2022. Tempo Online database of the INS (2021)	Z scores, outliers removed
Newly completed dwellings	NHB	Ratio between the number of newly completed dwellings and the total population in each intercensal period	Tempo Online database of the INS (1966–2021), www.insse.ro	
Urbanistic index	BI	Average share of households with access to water supply, sewerage and central heating out of the total number	Romania's population censuses of 1992, 2002, 2011 and 2022	
Educational index	EI	Share of people with secondary and higher education	Romania's population censuses of 1992, 2002, 2011 and 2022	
Income	INC	Average income from wages and social benefits (RON/person) extrapolated based on the socio-professional structure of the population	Tempo Online database of the INS (1966-2021), www.insse.ro	
Roma share	RR	Share of the Roma population (% of the total)	Romania's population censuses of 1992, 2002, 2011 and 2022	

In the end, four standardized data series resulted for each census (1992, 2002, 2011 and 2021). They were subjected to a multivariate analysis using the functions of the XLSTAT software. Considering the large number of explanatory variables and the high probability of multicollinearity, we opted for the PLS (partial least square regression) model, recommended in such cases. Based on the covariance analysis, the outcomes provided by this model are the correlation matrix, regression quality coefficients, factorial axis distribution plots, information on regression residuals, predictions, etc. The main results pursued were the correlation matrices, the distribution of the factorial axes and the *R2* coefficient, which were illustrated either in tables or graphs.

3. RESULTS AND DISCUSSIONS

3.1. Descriptive analysis

According to the above-mentioned methodology, the AHC (agglomerative hierarchical clustering) typological classification aimed at tracking the changes produced in the specific weight of each age group, without gender differentiation. In order to limit the excessive dispersion of the values within classes, raw data were standardized with Z-scores, removing outliers. The eight resulting classes are grouped into two unequal clusters (1-3 and 4-8, respectively), divergent enough to express time gaps in terms of the influence of some age-structure drivers, such as fertility decline, increased life expectancy, economic, social and cultural indicators (Fig. 1).

The profile of the classes overlapped, on the same graph, for each of them, the lines representing the specific weight of each age group, thus enabling us to track the changes that occurred over time due to the use of a unitary scale (Fig. 2). The eight classes are well highlighted, both from the perspective of their geographical distribution, significantly regionalized, and as regards their evolution profile.

The first cluster, which includes classes 1-3, mainly groups localities situated in the north-east, centre and south-east of the country. Characterized by a share higher than the national average of young people (aged 0−14) and a lower share of the elderly, the three classes differ in their spatial distribution and rate of change. Class 1, which includes 120 localities scattered mainly in the north-eastern and central part of the country, stands out through its resilience to the ageing process, preserving a very high share of the young population and a low, stable percentage of the elderly. The only notable change is the tendency of the population to increase in the 30−50-year-old range which, in the medium term, may point to the beginning of the ageing process. The areas are relatively coherent, closely linked to the preservation of a high female fertility rate, which is due to certain ethnic specificities (the presence of the Roma community) or confessional features (neo-Protestants), with a more conservative demographic behaviour (Muntele, 2023).

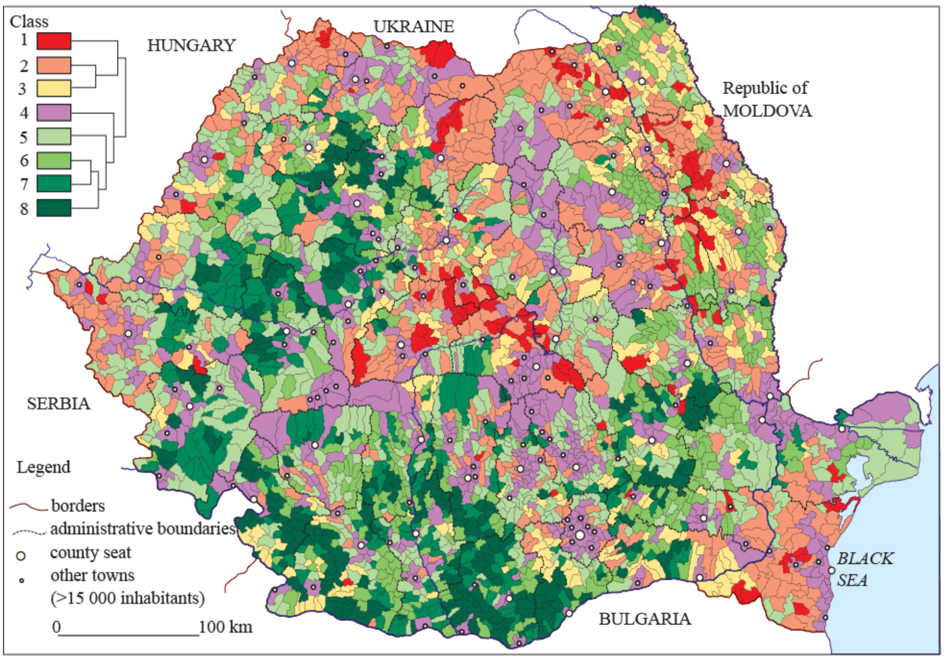

Fig. 1 – Typology of population structure by age groups.
(*Data source*: RPL 1992, 2002, 2011, 2021, INS).

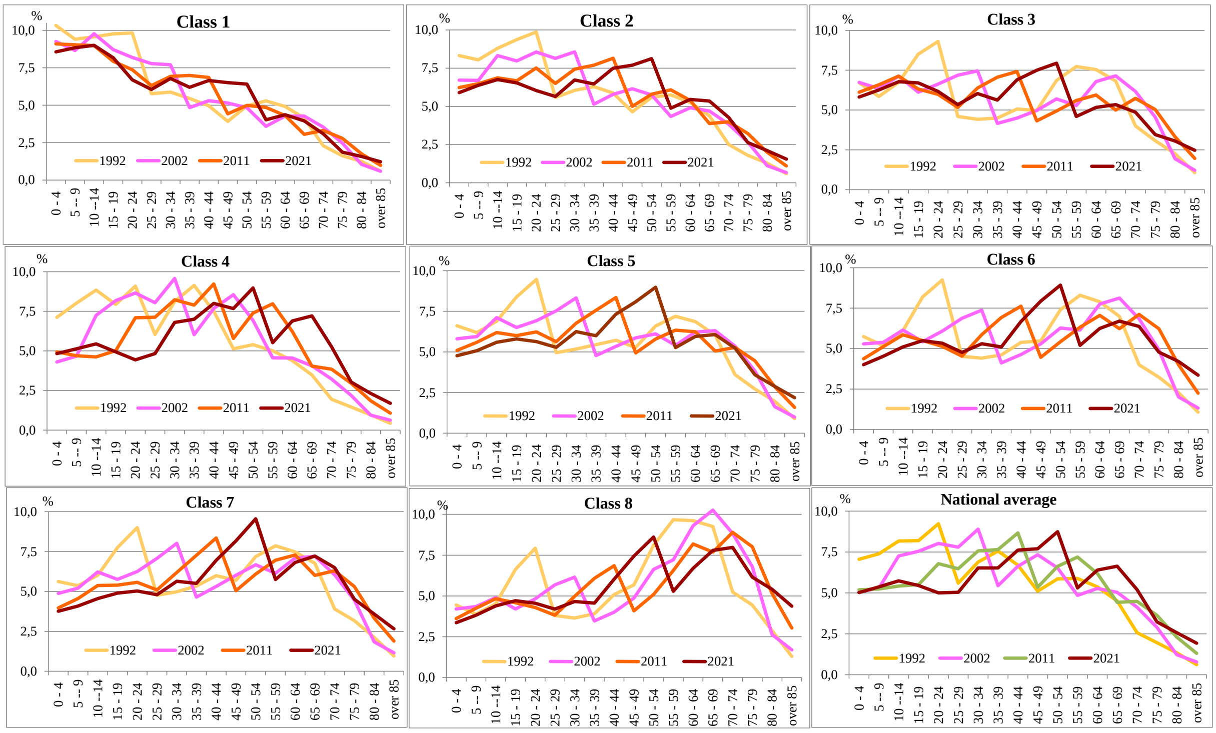

Fig. 2 – Classes profile. *Source:* own elaboration.

Class 2 is much better represented, grouping almost a fifth of the total number of localities (577 out of 3,181). It covers large areas which stretch over a significant part of some north-eastern (Iași, Suceava, Bistrița-Năsăud) or south-eastern counties (Constanța). Unlike the previous class, the tendency of the bottom to get narrower is more clearly expressed, and the augmentation of population at advanced ages (over 50) is much more obvious. It reveals a mature, relatively balanced structure, with a significant risk of ageing in the medium term. Class 3 comprises a smaller number of localities (233), forming larger areas, especially in the north-east of the country, in continuity with the previous classes, without being absent in the rest. It may be considered the more advanced version of classes 1 and 2, with an earlier decrease in the number of people in the younger age groups and a more significant increase in the number of the elderly; it is often located in rural areas remote from cities. The risk of short-term ageing is low, the 50-70-year-old generations, intensely represented in the years 1992 and 2002, recording a shrinking tendency. In the medium term, the evolution is similar to that of Class 2.

The first class in the second group (4) is well represented (592 localities) and forms very spatially coherent areas in the Carpathian Mountains and around important cities (Bucharest, Cluj-Napoca, Constanța, Timișoara). It is also typical of most urban centres, standing out through the swiftness of the transformations, both at the bottom, where the decrease in the share of the 0−30-year-old groups was very strong, and at the top, where the ageing process experienced a spectacular upsurge, fuelled by the massive augmentation of the adult population. This evolution pattern expresses the deep demographic changes felt after the fall of communism, stronger in these areas which had previously attracted large masses of young population, following the industrialization policy of the communist regime (Ianoș, 2001). The behavioural mutations, favoured by the larger share of the active population or by the higher level of education, brought about the profound drop in the fertility rate. Having become attractive again in the past decade, these areas can no longer secure their own workforce resources, having to call on regions that still have reserves, or even on international migration. Class 5, the most representative (615 cases), expanded all over the country, most often associated with class 4 in areas with relatively easy access to urban centres, and represents its more advanced version, with an earlier and massive but stabilized ageing process during the past two decades. It covers compact areas, most frequently in the intra-Carpathian regions and in the central-northern part of Muntenia, the most developed regions of the country. In the medium term, the risk of preserving the ageing level is relatively high because of the significant share of the 40-60-year-old age group, the circumscribed areas being less affected in the past both by the communist rural exodus and by international labour migration. Classes 6 and 7 have a similar profile and are spatially associated in rural areas located at an average distance from important urban centres. The highest frequency is found in the sub-Carpathian areas of Moldavia and Oltenia, or in the southern plain regions. The first of them (Class 6) is much better represented (526 cases), displaying a degraded structure, with low shares of the young population, an advanced ageing process and prospects of preserving this trend in the medium term. The other (Class 7, with 238 cases) is the even more serious version, mainly located in isolated mountain areas. The degradation of the bottom of the demographic structure (the young population) is severe, extending to the 40-year age group, with a massive augmentation at the level of the 50-64-year-old-groups. The relative stagnation of the ageing process during the past 20 years will, thus, be followed by a strong comeback. The last class (Class 8: 280 cases) reveals the most disharmonious structure, degraded even before the beginning of the study period, with a progressive and massive shrinking of the 0-39-year-old group and an excessive concentration for older-age groups. The significant increase in the oldest-age group (80+ years) is remarkable, at a level well above the national average. The ageing potential exceeded the maximum level, so that we may expect the relative shrinking or stagnation of the elderly population.

The spatial distribution of the changes in age structure overlaps the one derived from the analysis of the average age, used as a dependent variable in the factorial analysis. It is simpler and with a stronger homogeneity within the 6 selected classes (average intra-class dispersion is below 20%). The observed territorial differences can be explained through the evolution of fertility and life expectancy, with sufficiently clearly marked urban-rural disparities and well-defined regional distributions. The 6 classes are grouped in pairs, the first one having a slower evolution and the second one a faster one.

Class 1 coincides with the areas in the north-east and centre of the country, which preserve a still favourable age structure, with a share of adults above the national average. Consequently, the average age is much lower than in the rest of the country (Fig. 3, Table 2).

Class 2 is mainly typical of urban centres, but also covers extensive mountain areas (in the Eastern and Southern Carpathians), certain mining basins located in hilly areas (such as Motru) and agricultural regions with frequent state-owned agricultural enterprises during the communist period (particularly in Dobruja). The appeal they exerted prior to 1989 increased the number of the working-age population but, during the transition, it also fuelled a rapid transformation of the age structure. The significant rise in the average age of the population in these localities also reflects the more efficient access to medical services, with positive effects on life expectancy. However, immediately after 1990, the main impetus for changes was provided by the decline in fertility, more strongly felt in towns and localities with a population massively employed in non-agricultural activities. Labour migration (in particular of the younger population) gradually increased the average age. It is, perhaps, the most vividly felt effect of the transition, as the average age rose by about 10 years over the course of three decades.

Class 3 stands out through a slow growth, from relatively high values falling below the national average towards the end of the period. It is mainly specific to economically attractive and dynamic areas (the west of the country, the capital region), less affected by international labour migration. In 1992, class 4 recorded values well above the average, preserving a relatively strong increase, which reflects a more advanced ageing process. It is typical of more isolated mountainous and sub-mountainous areas or of the plain regions in the south-east of the country, and reflects the difficulties in adapting to the new conditions imposed by transition, against the background of a relative demographic stability during the communist period.

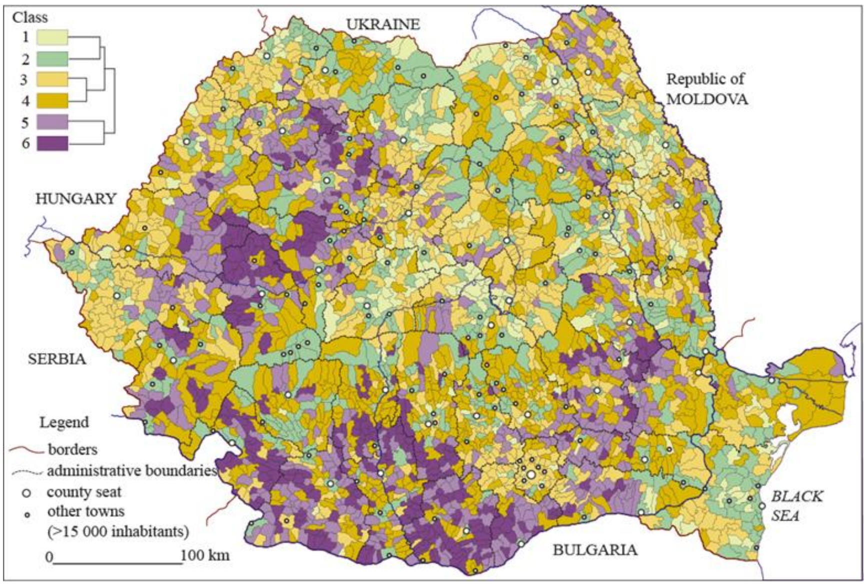

Fig. 3 – Typology of average age.
(Data source: RPL 1992, 2002, 2011, 2021, INS).

Table 2

Class profile

Class	Year			
	1992	2002	2011	2021
1	32.7	33.9	35.2	35.9
2	32.7	35.8	39.4	42.0
3	36.8	37.8	39.2	40.1
4	38.1	40.0	42.5	44.2
5	42.1	43.3	44.6	44.9
6	44.3	46.8	48.9	49.9
National average	**34.9**	**37.8**	**40.6**	**42.4**

Source: Own elaboration.

The last two classes have always ranked above the national average. They correspond to the vast demographically aged areas in the south of the country and in the Western Carpathians, and are positioned in territorial continuity, clearly differing from each other in terms of the speed of the evolution of this process. Class 5 stands out through its relatively stable values, which are much higher than the national average, and Class 6 with the preservation of an active dynamics, until around the 50-year-old limit towards the end of the study period. In both cases, the elevated average age emphasizes a drastic shrinking of the labour force potential and imminent depopulation trends, with irreversible effects in the most isolated localities.

The descriptive analysis thus highlighted the manifestation of some profound regional gaps in the evolution of the population structure by age. The patterns of evolution are well outlined spatially, closely related to the differential diffusion of the socio-economic modernization process. The present contrasts only certify the failure of the communist policies meant to homogenize the level of development. The transition which followed the fall of the communist regime disrupted the previous trends in evolution, already strongly marked by the gap between the urban and rural environments. New disparities have thus appeared, corresponding to the faster integration into the market economy circuit of various regions favoured by their geographical position (the west of the country, the metropolitan areas), or to the decline of certain activities that once provided stability, especially in mountain areas (mining, logging) or plain regions (marked by agro-industrialization). In terms of the average age, a major cleavage can be perceived between intra-Carpathian and extra-Carpathian areas. The first category, with the exception of the Western Carpathians, affected by depopulation, seem rather to correspond to some relatively stable evolution patterns. The others, except for the metropolitan areas (especially those that belong to the capital city), are more strongly marked by the aggressiveness of the ageing process. From this perspective, it may be stated that Romania holds an intermediate position between Hungary and Bulgaria. Thus, the average age in Romania increased by 21.3% between 1992 and 2021, from 34.9 to 42.4 years old, lower than in Bulgaria (23.3%, from 36.1 to 44.5 years old) but higher than in Hungary (19.3%, from 35.8 to 42.7). The western regions of the country have more so followed a central-European pattern, since in Banat the increase was of 20%, and in Crișana of just 15.2%. Dobruja has experienced a faster rise in the average age (by 25.3%), even higher than in Bulgaria. The contrast between western and southern areas is illustrated by the evolution of the average age in Crișana, a region on the border with Hungary, and Oltenia, which neighbours Bulgaria. Thus, from 36.5 and 36 years old respectively in 1992, it reached 42 and 43.6 years old, respectively, in the year 2021, a similar evolution to that of neighbouring states. In the rest of the country, the growth was closer to the average except for the capital and its metropolitan area (București-Ilfov), which recorded lower values.

3.2. Factorial analysis

The descriptive analysis of the typology of the evolution of the structure by age groups and of the dynamics of the average age pointed out the existence of some local and regional features, general trends and structural changes induced by the economic transition. All these cannot be correspondingly interpreted without the contribution of a multivariate analysis, integrating a series of relevant variables, within the limit imposed by the availability of information on this scale of detail.

The PLS-type multiple regression, performed on the 14 variables selected for analysis, corresponding to each of the 4 censuses taken into consideration (1992, 2002, 2011 and 2021) used the average age as a dependent variable. This choice was also stimulated by the homogenous distribution of the evolution trends identified at the spatial level; consequently, it is easy to interpret within a correlative analysis. The R2 coefficient of determination validates the factorial model through its high values, ranging from 0.555 to 0.603 (Table 3). The slightly decreasing trend of this coefficient between 1992 and 2002 may correspond to the disruption caused by the fall of the communist regime, while its subsequent recovery may be the expression of the manifestation of various forms of adaptation. Its satisfactory level is also given by the significant correlation of most of the explanatory variables.

At the beginning of the study period a strong correlation dispersion is revealed: 10 of the 14 factors recorded a value higher than a level indicating a significant influence (0.2). The AP, BI, HF, PEA and AB variables primarily stand out, illustrating the differences between the urban and rural environments, the latter being characterized by a more fragmented habitat, a lower urban comfort and massive agriculture employment rate of the active population. The augmentation of the elderly population, against the background of the birth rate decline, which began as early as the 1980s, already involves a strong influence of the ageing process at the top of the pyramid. But the other two forms of ageing (AB and MA) also have an important impact, as a consequence of the massive rural exodus specific to the communist period. The weak influence of certain factors can be explained by the context of the communist regime. For example, OO describes the stagnation of life expectancy during the last two communist decades, which limited the increase in the population aged 80 and over. The low level of the correlation with ALT points to the generalization of the ageing process, regardless of the geographical context. The lower value of the PMC emphasizes the limited polarization capacity of the main urban centres as a consequence of the strict planning policy of the party, which, from the urbanistic point of view, caused rural localities (even those situated in the proximity of towns) to lag behind. The gaps in the demographic behaviour that could be expressed by the cultural factor (as illustrated by the RR variable) are not so obvious, demographic transition being just in the process of completion.

Table 3

Correlation matrix of average age and explanatory factors

Variables	Average age				
	1992	2002	2011	2021	Trend
BA	**0.337**	0.070	**0.252**	0.168	decreasing
MA	**0,307**	**0,420**	**0.557**	**0.611**	growing
TA	**0.606**	**0.593**	**0.661**	**0.651**	high stable
OO	0.091	0.156	**0.251**	**0.338**	growing
ALT	0.114	0.071	**0.251**	-0.011	low stable
FS	**0.413**	**0.383**	**0.328**	**0.275**	decreasing
LMC	0.192	**0.214**	**0.212**	0.195	middle stable
AMT	**0.284**	**0.309**	**0.273**	**0.247**	middle stable
PEA	**0.343**	**0.349**	**0.285**	0.195	decreasing
NHB	**0.218**	**0.201**	0.19-5	**0.209**	middle stable
BI	**0.431**	**0.413**	**0.350**	**0.246**	decreasing
EI	**0.276**	**0.244**	0.158	0.040	decreasing
INC	**0.274**	**0.238**	0.171	0.058	decreasing
RR	0.102	0.168	**0.268**	**0.330**	growing
Coefficient R2	0.556	0.520	0.603	0.573	

Source: Own elaboration.

Based on these premises, the explanatory framework changes spectacularly a decade later, even though the augmentation of the elderly population (AP) is still the fundamental vector for the evolution of the ageing process. However, the role of median ageing also becomes more important. The significant increase in the PMC factor reflects the beginning of the suburbanization process, forced by the shrinking industrial activities and the rise in unemployment, following privatization measures. The distance from the city thus becomes an important vector for changes in the structure by age groups. The inertia induced by the massive accumulation of young population in cities, during the last two communist decades, preserves the explanatory value of the AMT, PEA and BI factors.

The main change introduced by the period before and after the accession to the European Union was the strong increase in the significance of the MA factor. This underlines the increasing (often permanent) international labour migration, against the background of easier access to the Schengen space. This context also brought about a slight drop in the birth rate, after having become stable at the end of the 1990s, hence relaunching the bottom ageing process. To all these we can add the sharp increase in life expectancy (from 70.8 to 74.2 years old between 2002 and 2011), which also strengthened top ageing. Their cumulative effect led to the fastest ageing speed during the analysed period, also visible in the significant correlation with the Oldest Old variable. Consequently, although between 1990 and 2002 the contingent of this category dropped from 280,000 to 258,000, in 2011 it rose to a spectacular 726,000, which is 3.6% of the total population. Among the variables that express urban-rural disparities, the ones related to education, income and dynamics of new housing constructions lose their importance. The others preserve a certain influence, but on a downward trend compared to the previous timeframe. This period also displays the stronger part played by cultural factors: the percentage of the Roma communities has now become an explanatory factor, dependent on demographic conservatism, which makes them resistant to the ageing process, but also prone to a lower standard of living, which is likely to limit the increase in life expectancy.

The last timeframe (2011−2021) captures new changes that certify the significance of the socio-economic changes that followed the accession to the European Union. The economic crisis of

2008–2011 and the pandemic crisis certainly played a role in these transformations. The importance of population mobility becomes more obvious than ever, the correlation expressed by the MA variable being very strong, similar to AP. The median ageing brought about by the continuous emigration of the young generations after the year 2001, along with the constant augmentation of the elderly population (derived from the numerous generations born after World War II) have also caused the *oldest old* category to increase (4.5% of the total in 2021). The steady increase in life expectancy (temporarily halted by the negative effects of the pandemic) also contributed to this. The variables that express urban-rural differences decrease in importance, but the explanatory value of the RR cultural variable increases.

The evolution of the explanatory capacity of the 14 variables can also be followed in a cross-sectional profile. Some of them experience a constant growth (MA, OO and RR), a perfect example of the role played by median ageing in the evolution of the transition of the age structure of the Romanian population, of the importance of the increasing life expectancy in the augmentation of the elderly population or of the preservation of a relatively high fertility rate in keeping a favourable structure. The stability of AP throughout the entire analysed period is remarkable, as well as that of the PMC, AMT and NHB variables, even though they have a smaller explanatory role. However, the other variables have experienced a downward trend. A stabilization of the fertility level during the last decades is thus validated, the specific fertility index ranging between 1.25 and 1.8, with its lowest values recorded at the beginning of the 2000-2010 period. Thus, the variation in the birth rate, which used to fuel bottom ageing in the past, has lost some of its importance. Variables such as habitat fragmentation, access to modern means of transport and a share of the agricultural population still play an explanatory role, but following a downward trend. This evolution may be related to the constant augmentation of peri-urbanization and metropolization. The massively decreasing explanatory role of income and educational variables may also be a consequence of the interference of some cultural factors, as proved by the rise of the RR variable. As a result, the high level of income and education seems to rather be correlated with an increased degree of ageing, reflecting the massive emigration of (especially well-qualified) young people. In this context, we can talk about a genuine explosion of urban ageing, even in the most attractive cities.

The analysis of the contribution of the variables with a strong explanatory value (BA, MA, TA and OO) has revealed four types of ageing within the Romanian space: early or uncertain; predominantly bottom ageing; combined ageing; predominantly top ageing (Fig. 4, Table 4).

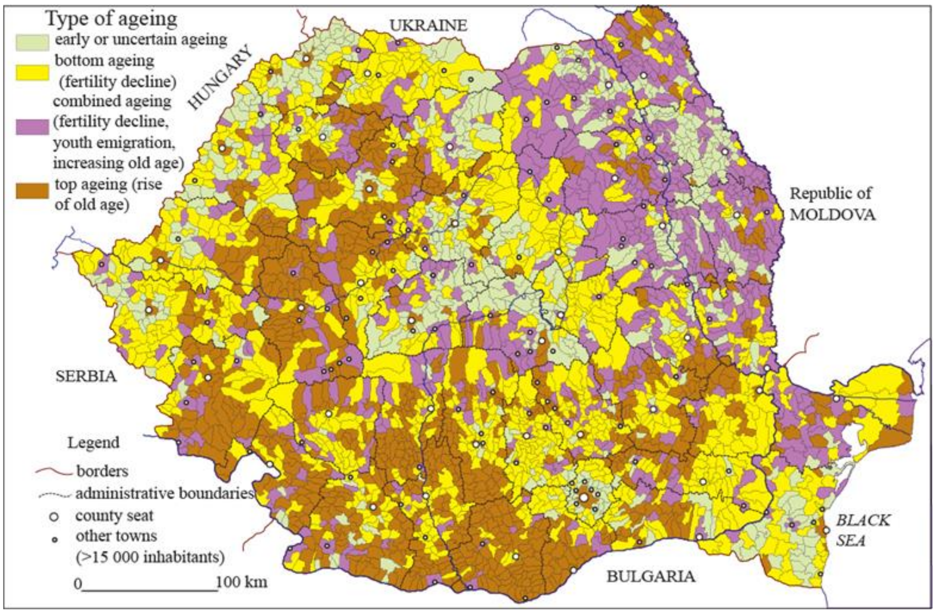

Fig. 4 – The typology of ageing in Romania according of the contribution of demographic variables.

Table 4

Ageing types profile (Data source: RPL 1992, 2002, 2011, 2021, INS)

Type	*Year*	*0−14 years*	*15−29 years*	*30−49 years*	*50−64 years*	*Over 65 years*	*Number of administrative units*
Early or Uncertain Ageing	1992	25.0	24.3	21.1	17.5	12.2	559
	2002	23.4	23.5	24.1	14.9	14.1	
	2011	22.2	20.3	27.4	16.0	14.1	
	2021	21.3	19.1	28.5	16.9	14.2	
Bottom Ageing (Fertility Decline)	1992	20.7	23.0	22.3	19.8	14.2	1056
	2002	18.9	21.6	25.0	17.5	16.9	
	2011	16.8	18.2	28.2	18.6	18.2	
	2021	15.4	16.6	28.3	20.3	19.4	
Combined Ageing (Fertility Decline, Youth Emigration, Increasing Old Age)	1992	21.5	23.8	21.5	19.5	13.6	702
	2002	19.8	21.0	24.2	17.3	17.8	
	2011	17.8	17.1	26.6	18.4	20.0	
	2021	16.1	16.8	25.6	20.3	21.2	
Top Ageing (Rise in Old Age)	1992	15.9	20.4	20.6	24.1	19.0	864
	2002	15.2	17.4	21.8	21.2	24.5	
	2011	13.6	14.6	24.6	20.2	27.1	
	2021	12.2	14.1	24.3	21.4	28.0	

Source: Own elaboration.

The first category groups those administrative units where the ageing process is either in an early phase, or uncertain in the short term. It circumscribes sufficiently vast areas in the north, east and centre of the country, but it also appears, sporadically, in the metropolitan areas of the main cities (Bucharest, Cluj-Napoca, Timișoara, etc.). The slower decline in fertility explains the preservation of a high share of the 0-14 and 15-29-year-old age groups. The middle part of the age pyramid is widening (especially in suburban areas), while the progress at the top is insignificant, resulting in a more balanced structure. These areas have become the main source of young labour force.

The second type is marked by bottom ageing, induced by the massive decline in fertility after 1990. It is the most characteristic, typical of the southern and central-western part of the country. Extending to intermediary rural spaces, located at a relatively short distance from the main urban centres, often advancing in suburban areas, it stands out through the constant and rapid decrease in the share of young age groups (0-14 and 15-29), the permanent augmentation of the young adult population (aged 30-49, which indicates a lower impact of emigration) and especially the strong rise in the share of the elderly population. Ageing will inevitably continue in these areas, being fuelled by the numerous middle age generations.

The third type is marked by combined ageing: at the bottom, median and at the top. It is particularly specific to north-eastern regions, dominated by intermediary or isolated rural areas. Compared to the previous type, it experiences a lower growth of the young adult population and a stability in the 50−64-year-old age group, massively involved in international labour migration. On the other hand, the share of the elderly population has rapidly progressed, generating a more advanced ageing process than in the previous case. This context suggests a slowdown of this process in the medium term, although it is possible that it will be fuelled by the return to the country of many who have emigrated in recent decades.

The last type stands out through the prevalence of top ageing, as an effect of the constant augmentation of the elderly population. Mainly specific to the south-west and west of the country (while also still to be found in the other sectors), it covers vast areas, sometimes overlapping entire counties (i.e., Teleorman, Hunedoara). The massive shrinking of the young population will maintain the spectrum of ageing in these regions, which, from the demographic point of view, are the most gravely affected. This group also comprises most urban centres, including the most important ones, urban ageing being, for the moment, a certainty in Romania. To a certain extent, this phenomenon is related to the tendency of young people to move to suburban areas which, as previously presented, are much less affected, sometimes even experiencing a revival of their age structure. The strongly regionalized territorial distribution of the four types of ageing proves the existence of specific patterns, generated by the interference of various factors, partially analysed using a multivariate analysis. This confirms the suggested hypothesis. We believe that a more profound investigation of the relationships between age structure and relevant demographic, socio-economic and cultural factors, at other scales of analysis, may provide additional explanations. It is the case of some previously mentioned phenomena, such as the revival of the population structure in metropolitan areas or urban ageing.

4. CONCLUSIONS

As a process that goes hand in hand with socio-economic modernization, demographic ageing recorded a relatively rapid development in Romania, in close connection with the shock felt after the collapse of the communist regime, which sped it up through its effects. We can state that the generalization of this process on the national scale is a certainty, proved by the almost threefold increase in the ageing index during the study period (from 0.48 to 1.21). Basically, over the course of a single generation, Romania has passed from a relatively young population structure, to one marked by intense ageing. Within the European context, the age structure of the Romanian population may seem more favourable, but this is primarily due to a lower life expectancy. Romania is far from the ageing level of Italy or Germany (1.65 and 1.76 respectively in 2021, according to Eurostat), but close to that of France (1.25 in the same year), countries with a constant intake of young adult population through migration. Comparatively, neighbouring states, such as Hungary or Bulgaria, with similar demographic characteristics, appear to be significantly older (1.39 in 2021). However, the speed of the ageing process was equally fast in Bulgaria or Hungary (the ageing index was of 0.54 and 0.65, respectively, in the early 1990s). Germany's value has been in excess of 1 even since 1990 (1.07), Italy was close to it (0.86) and France held an intermediary position (0.7). If ageing is indisputable at the national level, typological analyses highlighted the presence of several conservative areas where this process is in its early stages, or which faced a revival as a result of the influx of young population (the metropolitan areas) and where ageing is uncertain. In the case of the conservative areas, their isolation and predominantly rural character (often marked by certain ethnic or confessional specificities) can be treated as explanatory factors, as partially proved by the factorial analysis. The long differential evolution of the demographic transition, first in the south-west of the country and later in the north-east, is still valid, conservatory areas being concentrated mainly in the north-east of the country.

Significant gaps in the chronology of the manifestation and speed of the ageing process were emphasized. The main cleavage opposes the urban environment to the rural one. In just three decades, Romanian cities passed from an ageing index of 0.31 to one of 1.26. In contrast, in rural areas its evolution was slow, from 0.72 in 1992 to 1.16 in 2021. The main explanations that can be brought forth are: the increase in life expectancy (more consistent in the urban environment due to a better accessibility to medical services), the relative rural conservatism (fertility decline being much steeper in the countryside) and the increasing mobility, in various forms, which drains the young urban population in particular, either to neighbouring rural localities or to other countries. The fast urban ageing process that has manifested itself in post-communist Romania is in sharp contrast with the alert urbanization specific to the decades of forced industrialization. This reason is enough for a more thorough analysis of the causes, forms and effects generated by this insufficiently studied phenomenon. Significant gaps also appear according to other criteria, both in urban and rural regions. Hierarchy and administrative status produce distortions when it comes to cities, as does the position regarding urban centres with an important polarizing role in rural localities. In the case of cities, differences are not so significant but, in a seemingly paradoxical way, the evolution of the ageing index was much more accelerated in urban centres with over 50,000 inhabitants (generally county capitals), compared to medium or small cities (Table 5).

At the same time, large communes, with over 10,000 inhabitants, almost exclusively located in the proximity of the main cities, have faced a slower evolution, with rejuvenation trends even in the last timeframe. The transfer of the young urban population to suburban areas is thus certified, enabling connections between the decline of the urban population and the advancement of the ageing process correlated with the formation of metropolitan agglomerations. The compensation of this decline is often complete in the case of the large poles of development (especially the Capital).

Table 5

Evolution of Ageing Index by urban and rural hierarchy

Type of localities, by hierarchy	*Ageing Index*			
	1992	*2002*	*2011*	*2021*
Urban localities over 50 000 inhabitants	0.32	0.71	0.99	1.30
Urban localities with 10 000 - 50 000 inhabitants	0.28	0.55	0.83	1.19
Urban localities under 10 000 inhabitants	0.41	0.66	0.91	1.22
Rural localities over 10 000 inhabitants	0.40	0.60	0.67	0.64
Rural localities with 1 000 - 10 000 inhabitants	0.73	0.94	1.10	1.20
Rural localities under 1 000 inhabitants	1.23	1.72	2.06	2.39

Data source: INS, RPL of 1992, 2002, 2011, 2021.

Contrasts between rural localities are strong, the communes with a smaller number of inhabitants (prone to imminent depopulation) being heavily aged. Low accessibility, the predominantly rural character, and the more dispersed habitat partially explain this contrast, as validated by the factorial analysis.

The study certified the existence of certain regional evolution patterns of the ageing process, the role of the demographic decline having manifested after 1990 as a combination between fertility decline and the increasing international migration, as well as the local manifestation of a resistance, explainable by cultural factors. The factorial analysis proved the prevalence of the demographic factors, the ageing process being part of the perpetual restructuring of the population which is currently disturbed by the completion of the demographic transition. In Romania, this transition overlapped both the economic transition and the European integration which, in all probability, hastened the ageing process. At the same time, in the long term, the massive loss of young generations caused by international migration in recent decades will diminish the impact of ageing, provided that the status of the country changes from emigration to immigration (if possible).

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IMPLEMENTING GREEN INFRASTRUCTURE AND NATURE-BASED SOLUTIONS IN FLOOD RISK MANAGEMENT IN ROMANIA

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Key-words: green infrastructure, Nature-based Solutions, methodology, programmes of measures, areas with potential significant flood risk, Flood Risk Management Plans.

Abstract. The article briefly outlines the European legislative context on Green Infrastructure and Nature-based Solutions (NbS) by highlighting the main initiatives/laws published in the past 15 years, as well as the main definitions and associated concepts. One of the core aspects of the paper is the methodological approach proposed in order to integrate the Green Infrastructure and NbS elements into the Programmes of Measures (PoM) associated to the Flood Risk Management Plans (FRMP) – cycle II, reported to the European Commission – as required by the Floods Directive and approved by GD 886/2023. Compared to the proposed/carried out green measures during cycle I of the Directive's implementation, Romania has taken a big step forward. The implementation of the proposed green measures and NbS depends on numerous factors (local conditions, institutional issues, funding mechanisms, etc). Beyond the obvious benefits, the NbS have several limitations regarding their implementation. In conclusion, the article highlights the factors that favour the implementation of these measures, the restrictions that may appear, as well as the potential financing mechanisms.

1. INTRODUCTION. GREEN INFRASTRUCTURE AND NATURE BASED SOLUTIONS. THE EUROPEAN CONTEXT

Following the approval of the *EU's Biodiversity Strategy (2020)*, the need for the European Commission (EC) to develop a Green Infrastructure Strategy was established, in 2011, in order to reinforce the economic benefits that the EU's Biodiversity Strategy brings and to attract greater investment in Europe's natural capital. Thus, in 2013, the European Commission approved the *EU's Green Infrastructure Strategy* which included four priority workstreams: promoting green infrastructure in key policy areas; improving information, strengthening knowledge and promoting innovation; improving access to finance and developing the Green Infrastructure projects at EU level (European Commission 2013). The EU's Green Infrastructure Strategy supports the full integration of Green Infrastructure into EU policies so that it becomes a standard component of territorial development throughout the Union.

Nowadays, Green Infrastructure and NbS have become essential components of the newest European legislative initiatives, as follows: the *EU's Green Deal*, the *EU's Biodiversity Strategy for 2030*, the Cohesion Fund and the Cohesion Policy, the *EU's Strategy on Adaptation to Climate Change*.

According to the latter, the European Union aims to achieve climate neutrality by 2050 and measures such as Green Infrastructure and Nbs can provide a wide range of benefits to society, from

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carbon storage to clean waterways, while also reducing the impact of climate change and improving flood protection, without bringing any harm to the environment.

According to the *Nature Restoration Law*, recently approved by the European Parliament (Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869), measures ought to be in place by 2050 for all ecosystems in need of restoration. The law covers degraded terrestrial and marine habitats, pollinators, agricultural ecosystems, urban areas, rivers and floodplains, forests.

Regarding the rivers and floodplains, more than one million artificial barriers, such as dams, spillways and weirs, are built on Europe's rivers (European Environment Agency 2021). The new rules would aim to remove many existing barriers on these EU rivers to ensure a greater continuity throughout the river networks. The law sets a target of at least 25,000 km of free-flowing rivers by 2030. As data on river barriers is still insufficient, one of the aims for these new rules is to draw up an inventory of barriers across the EU. Removal efforts should be focused on outdated and out of use barriers. At the same time, Romania will have to prepare and submit to the European Commission a National Restoration Plan to demonstrate how the proposed targets will be achieved through this law.

All these European approaches and legislative initiatives are nothing more than a series of obvious steps to support and promote the large-scale implementation of Green Infrastructure and NbS in different fields of activity.

Therefore, this article aims to highlight the importance of measures such as NbS and Green Infrastructure, as a strategic approach of major importance in the national legislative initiatives, associated action plans, or investment plans. A relevant example is the Programme of Measures associated with Flood Risk Management Plans – Cycle II (Ministerul Mediului, Apelor și Pădurilor 2023), a methodological approach to which the authors have made an important contribution, focusing on integrated flood risk management, ecosystem conservation, and the consideration of the multiple socio-economic benefits.

In this context, we recall the main provisions of the Floods Directive (European Commission 2007), which uses as a planning tool the Flood Risk Management Plan:

– The first stage – Preliminary flood risk assessment – involves the nationwide identification of significant historical floods and potential future significant floods (in terms of recorded/ potential damage) and the delineation of areas with significant potential flood risk (Areas with Potential Significant Flood Risk – A.P.S.F.R., 526 delineated areas in Romania);
– The second stage – The development of hazard maps and flood risk maps for APSFRs (outlined during the previous step) under different flood scenarios;
– The third stage – The elaboration of Flood Risk Management Plans for all 11 Water Basin Administrations, as well as for the Danube River, based on the above-mentioned maps; the 12 Plans include proposals for flood risk reduction measures for APSFRs as defined during the first stage of the Floods Directive 2007/60/CE implementation.

2. GREEN INFRASTRUCTURE AND NATURE-BASED SOLUTIONS – DEFINITIONS AND CONCEPTS

"Green Infrastructure" is a term that is becoming more commonly used among natural resource professionals. While it may mean different things to different people depending on the context in which it is used, Green Infrastructure is an interconnected network of green space that preserves natural ecosystem values and functions, and provides associated benefits to human populations. Green Infrastructure is the ecological framework needed for the environmental, social and economic sustainability of our nation's natural life support system (Benedict A. M., McMahon T. E., 2002).

Among the main benefits of Green Infrastructure is that it helps protect and restore naturally functioning ecosystems by providing a framework for future development that fosters a diversity of ecological, social and economic benefits. These include an enriched habitat and biodiversity, the maintenance of natural landscape processes, cleaner air and water, increased leisure opportunities, improved health, and a better connection to nature and a sense of place. Green space also increases property values and can decrease the costs of public infrastructure and services such as flood control, water treatment systems and storm water management (the flood management infrastructure, water treatment plants, and stormwater management techniques) (Mell C. I., 2017).

Green Infrastructure should be carefully planned, designed, and expanded as communities grow. Green Infrastructure planning should be the first step in developing land-use plans, and should be coordinated with planning roads, sewers, water lines and other essential grey infrastructure. Integrated planning and design should connect green and grey in a more effective, economic and sustainable network. Green infrastructure should be:

- designed holistically – Green Infrastructure should be designed to link elements into a system that functions as a whole, rather than as separate, unrelated parts;
- planned comprehensively – our green space systems need to be planned to include ecological, social and economic benefits, functions and values;
- laid out strategically – Green Infrastructure-based systems need to be laid out strategically, to become feasible from a legislative point of view;
- planned and implemented considering the input from the public, including community organizations and private landowners;
- grounded on the principles and practices of diverse professions – Green Infrastructure-based systems should rely on solid science knowledge of professional disciplines such as landscape ecology, urban and regional planning, and landscape architecture;
- funded up-front – like other infrastructure systems, our Green Infrastructure needs to be funded as primary public investments rather than with money left over after all other services have been provided. (Coutts C., Hahn M., 2015; Mell C.I., 2017).

NbS are inspired and supported by nature, and are cost-effective, providing environmental, social and economic benefits and contributing to an increased resilience. In addition, NbS have a particular importance in addressing climate change impacts and managing the biodiversity “crisis” by providing green/ecological solutions. In the NbS category, the following are among the most popular types of measures (Ministerul Mediului, Apelor și Pădurilor 2023):

- Upland and gully woodlands. Afforestation of upper areas of torrential river basins;
- Wider catchment woodland. Large-scale afforestation of hydrographic basins;
- Woodland management. Floodplain and riparian woodlands management;
- Reduction of slope runoff through anti-erosion forest curtains (agroforestry systems);
- Reduction of local slope runoff through earthworks or the use of “surface runoff barriers”;
- Improvement of lands affected by deep erosion or surface erosion (by afforestation) – requires terracing, erosion barriers, etc.;
- Promoting and implementing best practices in slope agriculture (e.g., cultivation practices for soil conservation);
- Re-meandering, restoring channel and floodplain features;
- Leaky barriers;
- NWRM – Offline storage areas;
- Coastal management – beach recharge;
- Removing works that regulate flows;
- Assessing the setting back, partial or full removal of flood embankments.

3. THE METHODOLOGY FOR THE INTEGRATION OF GREEN MEASURES IN THE FLOOD RISK MANAGEMENT PLAN IN ROMANIA

In Romania, some elements related to Green Infrastructure and NbS have been integrated, based on a dedicated methodology, in the Programmes of Measures associated with the Flood Risk Management Plans – cycle II, as approved by GD 886/2023 and reported by the Competent Authority (National Administration "Romanian Waters") to the European Commission.

Furthermore, the entire Methodology for the elaboration of the Programmes of Measures (developed with the contribution of the authors under the *Technical Support for the development of methodologies, for the Flood Risk Management Plans* contract closed in 2021 with the World Bank as the beneficiary) has emphasized the integration of as many green measures as possible in the development of the Programmes of Measures, proposed at the level of each *Areas with Potential Significant Flood Risk* (APSFR). All these Programmes of Measures form the core of the Flood Risk Management Plans, elaborated at the River Basin Administration (RBA) level.

These Plans were developed within the framework of a subsequent project, namely *Consultancy services for the elaboration of Flood Hazard and Risk Maps and Flood Risk Management Plans for Romania*. This was a project coordinated also by JBA Consulting (consortium leader), whose client was the World Bank. These consultancy services were foreseen within the framework of the Financing Application called *Strengthening the capacity of the central public authority in the water field for the implementation of the 2nd and 3rd stages of Cycle II of the Floods Directive - RO-FLOODS (SIPOCA Code 734),* whose final beneficiary was the Ministry of Environment, Water and Forests and the National Administration "Romanian Waters". The main methodological steps taken are shown schematically in Figure 1.

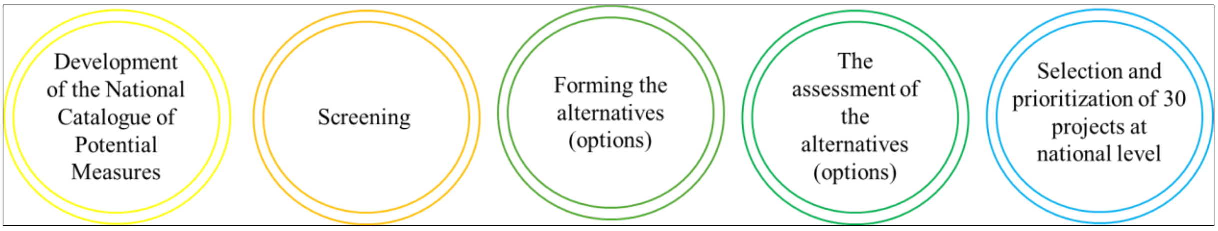

Fig. 1 – Presentation of the main methodological steps followed in the elaboration process of the Programmes of Measures included in Romanian FRMPs.

The Methodology has allowed the identification of prevention, protection, preparedness, response and recovery measures, prioritizing, where possible, non-structural measures and NbS. The integration of NbS into the Programme of Measures aimed to maximize the multiple benefits of the proposed measures. The way in which Green Infrastructure and NbS have been prioritized at all development stages of the Programme of Measures is detailed below, as follows:

- **The Development of the National Catalogue of Potential Measures** (Ministerul Mediului, Apelor și Pădurilor, 2023), according to the typology of measures described in the reporting requirements of the EU Flood Directive. It included a total of 64 measures categories (each measure with its own associated code), among which four measures categories correspond to the typology of green measures, as illustrated in Figure 2.

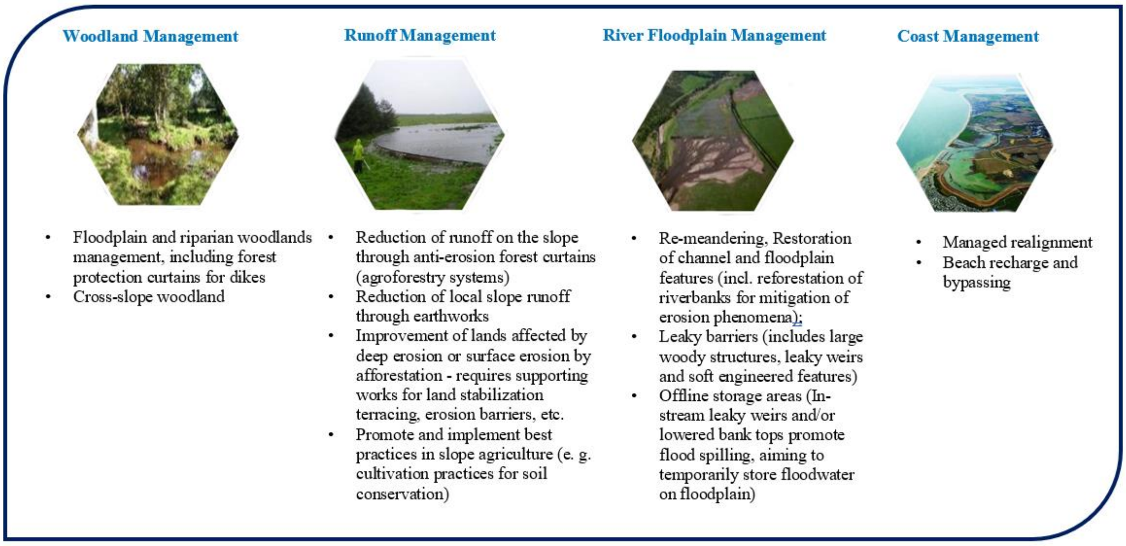

Fig. 2 – Types of green measures proposed in the National Catalogue of Potential Measures.

- **Screening** – the process entailed drawing up a "long list" of potentially viable measures for each APSFR (5500 potential measures in all 526 APSFRs at the national level). The viability of measures was preliminarily assessed based on technical, social, cultural, heritage, environmental and economic considerations. Regarding the "Environment" criterion, the aspects targeted were those mainly related to the negative impacts on the water bodies' status and the negative impacts on Natura 2000 sites/species. Thus, the following issues needed to be considered for this criterion (in other words, the questions that needed to be addressed) have been established:
  – *Is the measure likely to have a negative impact on the water body status?* This was based only on the type of measure and its potential impact. Moreover, only the main structural measures were considered at this stage (reservoirs, dykes, bed regularization works);
  – *Potential impact on upstream/downstream water bodies (Art. 4(8)).* This was also based on the type of measure and the potential impact;
  – *Are there some feasible practical ways to mitigate negative impacts?* Mitigation measures were mainly considered from the Factsheets attached to the Catalogue of Potential Measures associated with the FRMP. In addition, mitigation measures - in order to mitigate the impacts of hydromorphological alterations for rivers, lakes and coastal waters in the River Basin Management Plan (Cycle III) - have been considered to be integrated into the Flood Risk Management Plan strategies (where applicable);
  – *Can the same benefits be achieved by alternative measures?* By answering this question, it was verified whether possible alternative measures were eliminated too early in the Programme of Measures process during the Screening stage. By default, all the NbS proposed at the level of all APSFRs were retained in the screening analysis.
- **Forming the alternatives (options)** (JBA 2023a) - the process consisted in grouping the measures resulting from the screening process ("short" list of measures obtained after the assessment made on technical, social, cultural, heritage, environmental and economic considerations) into alternatives (options) at the APSFR's level; in forming the alternatives, the Methodology recommended was to start from green measures, followed by non-structural measures, "light" structural measures and then "heavy" structural measures. This hierarchical proposal of measures that formed the alternatives is presented in Figure 3.

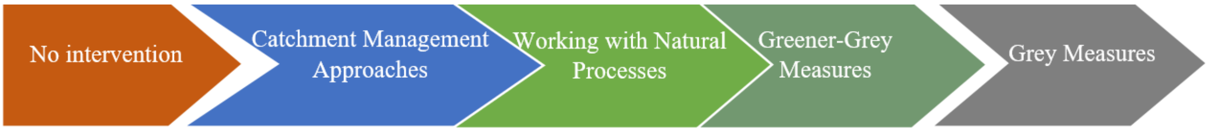

Fig. 3 – Hierarchical approach in order to integrate green measures into the alternatives' (options') development.

The figure schematically illustrates the methodological approach for integrating NbS and Green Infrastructure into Programmes of Measures. The methodology proposes a hierarchical approach for integrating green measures into the formation of alternatives, detailed as follows (Roca *et al.*, 2017):

- **No Intervention**
  - A flood management strategy that allows the natural adjustment of the watercourse without any human activity; it may require changes in the current use of the river and floodplain;
  - The opportunities and constraints for these types of measures are usually linked to the settlement pattern;
  - Avoiding development in the floodplain is an example of a no-intervention measure.
- **Catchment Management Approaches**
  - Management options involve a wide variety of interventions of change in practices to reduce runoff, manage sediments and improve the operation of infrastructure;
  - Examples include: public awareness, fencing of dikes to protect from livestock, optimizing operating rules of existing infrastructure, changing maintenance regimes, and improving how forestry is managed in the upstream catchment and adjusting agricultural practices to reduce runoff and improve soil condition.
- **Working with Natural Processes**
  - Measures which work with and respect the natural hydrology and sediment regime of the river system. These include catchment scale measures for river and floodplain measures to alleviate or delay river discharge, enhance floodplain conveyance, and reduce peak flood levels;
  - The aspirational objective is for a free-flowing river;
  - Suitability is constrained by floodplain slope, urban development and confined valleys.
- **Greener-Grey Measures**
  - Softer structural measures which include natural materials, more natural form or specific measures to enhance or create habitats.
  - In some situations (e.g., Heavily Modified Waterbodies) the natural functioning of a river and its floodplain cannot be restored; in these situations, all possible opportunities to work with natural processes to reach a situation which is as free flowing as possible should be explored.
- **Grey Measures**
  - Hard structural engineering measures, which typically use artificial or concrete materials;
  - Only to be used if all other approaches are exhausted;
  - For grey measures to be acceptable, the project needs to demonstrate compliance with EU Directives (specifically, the revised EIA Directive, the Water Framework Directive, the Habitats and Birds Directives).

- **The assessment of the alternatives (options)** was carried out through a Multi-Criteria Analysis and Cost-Benefit Analysis using the *Appraisal Summary Tool* (AST). The AST integrates 8 environmental indicators *(pollution, biodiversity, fisheries, watercourse functioning, water quality and quantity, soil quality, vulnerability to climate change and CO_2 greenhouse gas sequestration)* in order to illustrate the potential benefits for the baseline situation and the proposed alternative(s). *The biodiversity and river functionality indicators* value the NbS by scoring them in the alternatives' comparison and evaluation analysis. Based on this analysis/assessment, the preferred (recommended) option was selected, which became the Strategy (Programme of Measures) at the APSFR level.

- **Selection and prioritization of 30 projects at the national level** (JBA 2023b) (see their locations in Figure 4), aims to develop the investment and implementation plans for over a 10-year period. One of the criteria for defining of integrated projects refers to the **"existence of green measures"**. Therefore, integrated projects contain, in addition to traditional engineering measures, an important component of green measures. Among these, the most relevant *win-win* measures (supporting the achievement of the objectives of both directives the following types of measures are mentioned, each measure having an associated code (in order to understand the coding of measures, please refer to *the National Catalogue of Potential Measures*, https://inundatii.ro/wp-content/uploads/2023/09/Sinteza-Nationala-PMRI-Ciclul-II.pdf, p 151)): *The re-meandering of waterways, The restoration of channel and floodplain features (incl. the reforestation of riverbanks for the mitigation of erosion phenomena)* (M31-RO17), *Offline storage areas (In-stream leaky weirs and/or lowered bank tops promote flood spilling, aiming to temporarily store floodwater in the floodplain*) (M31-RO19) and *The assessment of relocation, partial or full removal of flood embankments* (M33-RO36). These are the measures ensuring lateral connectivity, improving the morphology of banks and riparian areas, while also reducing the flood risk. Particular importance has also been given to green measures involving afforestation, such as:
  - *Maintaining or increasing the proportion of forested area in the upper basins of watercourses (not only APSFR)* (M31-RO10);
  - *Maintaining or increasing the area of forests intended for: hydrological protection and intended for land and soil protection* (M31-RO11);
  - *The management floodplain and riparian woodlands, including forest protection curtains for dikes* (M31-RO12);
  - *Reduction of slope runoff through anti-erosion forest curtains (agroforestry systems)* (M31-RO13);
  - *Improvement of lands affected by deep erosion or surface erosion (through afforestation) – requiring terracing, erosion barriers, etc.* (M31-RO15).

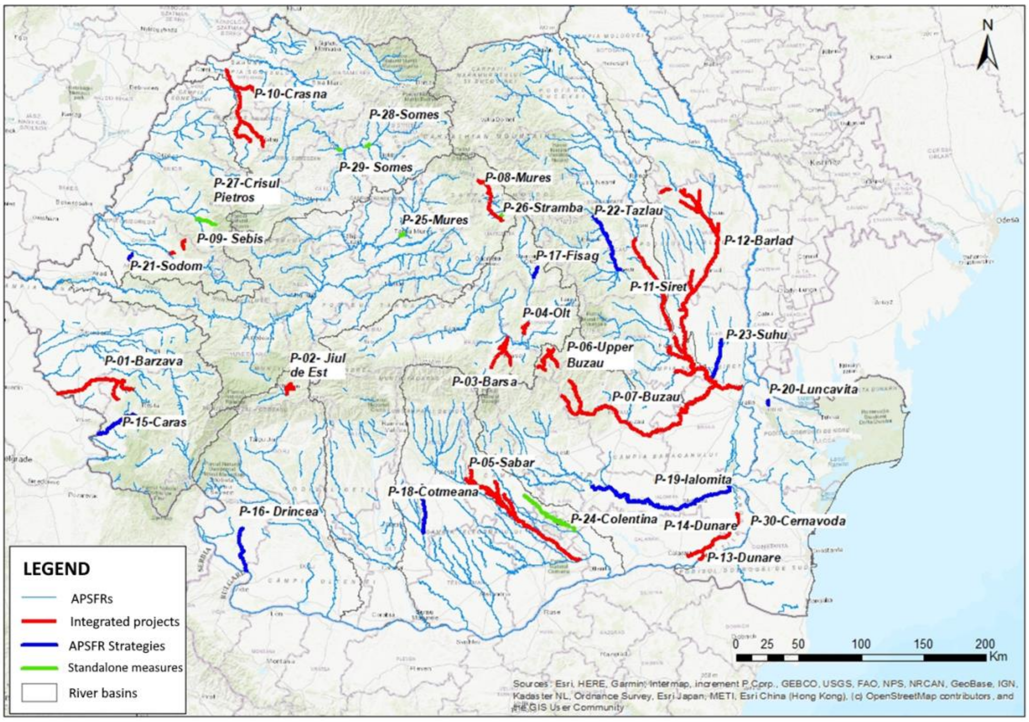

Fig. 4 – Locations of the 30 projects at national level.

In the process of defining potential measures for Integrated Projects, a method for identifying areas with afforestation potential has been applied. Thus, such measures as *M31-RO10* have been proposed on the identified areas for the 30 prioritized projects; at the national level, two aspects of interest have been emphasised, namely: **the maximum theoretical area proposed for afforestation** is **481,127 ha** (time horizon – about 35 years) and **the viable area proposed for afforestation** is **17,213 ha** (time horizon – 10 years). It is important to mention that two correction factors have been applied to the above theoretical/potential land area: an implementability factor, applied to the theoretical area to reflect the one viable to be afforested for flood risk management purposes, and a reduction factor applied so as to reflect what is technically feasible to implement over the next 10 years. The implementability factor is intended to capture the uncertainty of the process of engagement with landowners and stakeholders, which is a very complex and dynamic process that cannot be defined *a priori*.

GREEN INFRASTRUCTURE AND NATURE-BASED SOLUTIONS – CURRENT STATUS, TREND, FAVORABLE CONDITIONS, OBSTACLES, FUNDING MECHANISMS

A comparative status of flood risk management plans – Cycle I vs. Cycle II from the perspective of green measures.

Analysing the elaborated Programmes of Measures, we were able to make a comparative centralized situation of the green measures at the national level, taking into account the first and second Cycles, considering the three main green measures types from the above-mentioned Catalogue (M31-RO17 *River Re-meandering/Restoration*; M31-RO19 *Natural Water Retention Measures*; M33-RO36 *Partial or full dike removal/relocation*).

As shown in the Figure 5, the Flood Risk Management Plans developed in Cycle II contain 80% more green measures than the versions developed as part of Cycle I of the Flood Directive implementation.

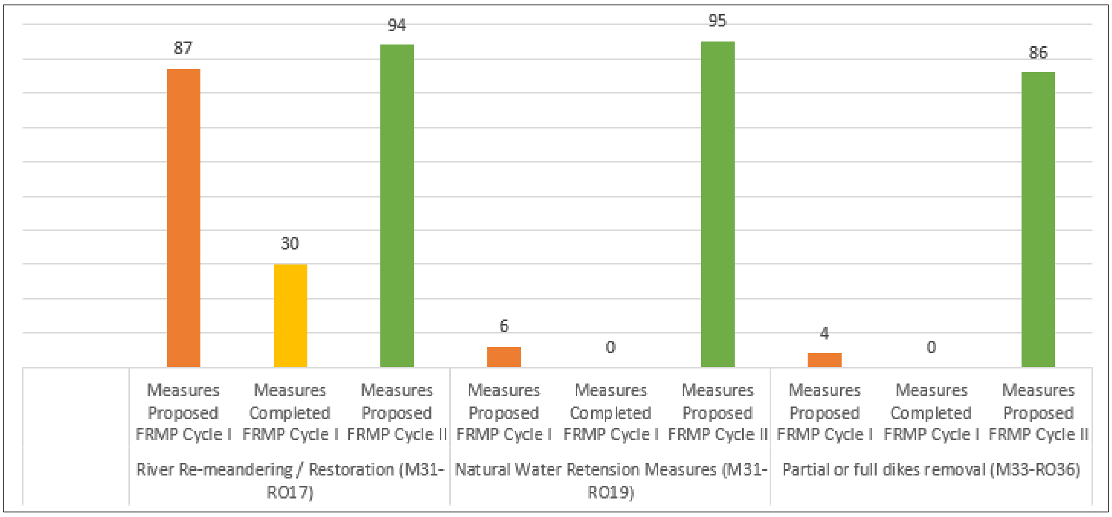

Fig. 5 – Comparative analysis of green measures (Cycle I vs. Cycle II). National situation.

Favourable conditions

Among the main factors that facilitate the development of these projects (which include NbS in Romania) are:

- stakeholder involvement in the implementation of projects that promote Nbs; to overcome mistrust in “soft/green engineering” processes, collaboration, rather than consultation, is needed;

- the existence of a specific legislative framework to promote and support the implementation of these types of solutions;
- the possibility of non-refundable funding;
- the interest of local decision-makers;
- the educational, awareness-raising potential of the population and, in particular, decision-makers regarding the long-term benefits of NbS. In addition to fulfilling its purpose and objective, there is a wide range of additional benefits, such as: wildlife and fish spawning habitat improvement, water quality improvement, natural processes restoration, recreational areas development and enhancement, etc.
- compared to conventional solutions, green approaches are often associated with lower capital costs and a wider range of benefits. In general, green approaches can be financially supported through a wide range of subsidies, can have a lower whole-life cost and can be more cost-effective when combined and integrated with grey solutions.

Obstacles (Difficulties in implementation)

Regarding the restrictions in the implementation of these projects promoting NbS, the main obstacles are related to legal land ownership and the lack of good practices in Romania, in terms of the conceptualization and design of these types of investments.

Moreover, an important limiting factor is that infrastructure elements which integrate NbS provide partial protection for the areas at risk during extreme flood events. At the same time, when discussing various protection measures (e.g., tree plantations, vegetative protections), the effect is not immediate, sometimes requiring 3–5-year cycles, during which the objectives requiring protection, as well as the works themselves, are vulnerable. For this reason, depending on the local hydro-morphological conditions, it is necessary, in certain situations, to bolster these solutions/measures with light, environmentally friendly structural measures (using local materials, such as earth-filled timber works, dry masonry works, etc.) or, where appropriate, with grey infrastructure elements (traditional engineering measures). It is fundamental that the engineering performance of any green measures fulfil the legal requirements. Also, it is important to mention that the targeted standard of protection can be achieved either by an individual (singular) measure or by a set of measures (flood relief scheme) - sized so that, together, they might meet the target standard. In some cases, achieving the target standard of protection may not be realistic due to economic, technical, social, cultural or environmental constraints; in these cases, the target standard of protection may be adjusted, justified, on the basis of a rigorous risk analysis and a techno-economic analysis. In this case, if possible/feasible, some measures will be put forward in order to increase the resilience of flood-exposed targets (individual adaptation measures).

Some additional and limiting factors in implementing NbS, mainly in Romania, include:

- difficult inter-institutional collaboration;
- the lack of awareness and education regarding the benefits and importance of NbS, or a conflict about the existing economic interests;
- the lack of trained specialists for the conceptualization, design and implementation of these types of projects, as well as the lack of an "ecological sense" among decision-makers;
- the existence of compensation mechanisms in order to support the use of privately owned land; there are additional difficulties in Romania because of the land on which measures need implementing to work with natural processes. The land is often outside the area that the River Basin Administrations and the National Administration "Romanian Waters" can use. Complex land transfer and management agreements are needed.

Nowadays, NbS have a great potential to obtain funding from the EU, and in order to be eligible for EU funding, the strategy and projects need to be in line with EU policy, strategy and directives.

Funding mechanisms

The European Commission is helping EU Member States with this green transition, to achieve the objectives of the European Green Pact and the subsequent legislation. With a view to implement Green Infrastructure, the European Commission has developed various funding programs, among which we mention:

- HORIZON Europe - aims to strengthen the European Union's science and technology base, including by developing solutions to address policy priorities such as the green and digital transitions. The programme also contributes to sustainable development goals and boosts competitiveness and growth;
- LIFE – for the funding of water resources management projects; it is divided in three sub-programmes:
  - **Nature and Biodiversity**, which aims to protect and restore Europe's nature, stopping the loss of biodiversity. This sub-programme supports projects that contribute to the implementation of the Natura 2000 network and support the achievement of the objectives of the EU's Biodiversity Strategy 2030;
  - **Climate Change Adaptation** – under which projects can be funded for NbS development and implementation, for different types of areas (rural, urban and coastal), water management, financial instruments, innovative solutions and public-private collaboration on insurance and on the date regarding incurred damages;
  - **Governance and knowledge on climate**, which supports the European Climate Pact's functioning, awareness raising, training and capacity building, knowledge development and stakeholder engagement in the areas of climate change mitigation and adaptation.
- The European Agricultural Fund for Rural Development (EAFRD), the European Agricultural Guarantee Fund, the European Regional Development Fund, Cohesion Funds, etc.

5. CONCLUSIONS

The article provides an overview of the European legislative framework concerning Green Infrastructure and nature-based solutions, along with the key associated definitions and concepts. Building on the authors' experience from two World Bank-funded projects conducted over the past three years in Romania (nationwide projects), the article introduces the proposed methodological approach for integrating Green Infrastructure elements and nature-based solutions into the Programmes of Measures associated with the Flood Risk Management Plans – Cycle II. The discussion emphasizes the evolution/trend of promoting and implementing these measures in Romania, the enabling factors that support their adoption, the potential challenges, and the main available EU funding mechanisms.

In conclusion, based on the analysis presented in this article, Figure 6 offers a schematic representation of the **key drivers for promoting and implementing green measures** in Romania.

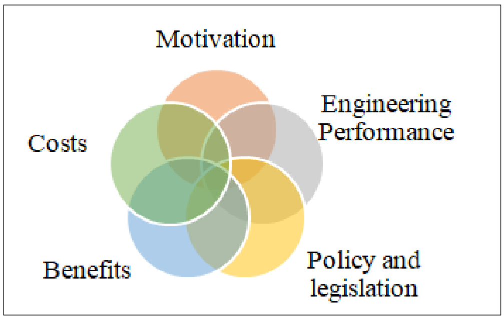

Fig. 6 – Key factors for promoting and implementing green measures.

Therefore, comparing the benefits of these measures against the costs and the reduced environmental impact, we deem it appropriate to more extensively integrate Green Infrastructure and NbS in river basin management schemes. Therefore, the benefits of Green Infrastructure may contribute to climate change adaptation and mitigation. In addition to the water risk phenomena management (floods, droughts), the measures focusing on the implementation of this type of infrastructure offer other benefits as well, such as: improving the local climate, improving water and air quality, ensuring conditions for the development and conservation of biodiversity (including that which is specific to urban areas), facilitating the development and protection of green spaces/recreational areas, and the benefits associated with the population's health and well-being.

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MODÉLISATION DE L'INTERDÉPENDANCE ENTRE LES RÉSEAUX TECHNIQUES URBAINS DANS LE GRAND LOMÉ (TOGO)

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Key-words: natural disasters, interdependence, modelling, urban networks, Togo.

A modelling of the interdependence between urban technical networks in Greater Lomé (Togo). Infrastructures are at the service of human activities and play an essential role in the development of any society. In recent years, social and infrastructural systems have often malfunctioned, due to the increase in natural and man-made disasters on the one hand, and the internal and external dependencies between system components on the other. The interconnection between social-infrastructural systems means that the damage caused to a single system extends beyond its reach. This study analyses the functional interdependencies between social-infrastructural systems. To this end, it reviews current literature in these respective fields to identify the challenges posed by urban technical networks in Greater Lomé (Togo). The modelling and assessment carried out by this study also identifies gaps in knowledge and tools to support existing infrastructures and those at the planning stage. The study reveals that every major element in the information and decision chain – from the frequency and intensity of a disruptive event, to the assessment of the immediate and first-order impacts of infrastructure failure, to the estimation of the nature, extent and impact of cascading failures – multiplies uncertainties. The results provide a guideline for decision-makers to improve the functional interdependencies of urban systems.

1. INTRODUCTION

Le terme "urbain" fait référence à une caractéristique de lieu liée à la transformation de l'environnement naturel en un environnement construit. Une ville, ainsi qu'une zone urbaine, sont des systèmes complexes composés de multiples sous-systèmes, et nombreuses sont les interactions entre ces sous-systèmes et l'environnement extérieur. Selon Meerow *et al.* (2016) il existe quatre types de sous-systèmes dans le système urbain: les systèmes technico-infrastructurels (systèmes infrastructurels), les systèmes socio-économiques (systèmes sociaux), les systèmes de nature et de flux d'énergie (systèmes environnementaux) et les systèmes gouvernementaux-organisationnels (systèmes organisationnels).

Selon Reghezza-Zitt (2005), la ville est perçue comme un système complexe qui regroupe de nombreux enjeux sociaux, économiques et humains. Elle est souvent considérée comme un lieu présentant une multitude de dangers et de risques variés, intrinsèques à l'environnement urbain. Ces dangers découlent principalement de l'exposition des éléments vulnérables aux aléas naturels ou humains. Lorsqu'une catastrophe survient, les dégâts directs et indirects causés par cette exposition sont donc une manifestation du risque et de la vulnérabilité (Pigeon, 2012). Les réseaux techniques urbains apparaissent, lors de ses différentes catastrophes, non seulement comme le point d'ancrage de la vulnérabilité (Serre *et al.*, 2014), mais aussi comme agent vecteur de cette même vulnérabilité.

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Selon Bocquentin (2020), Grangeat (2017), Toubin (2014) et Lhomme (2012), la notion de « réseau technique urbain » peut être interprétée de manière différente en fonction des domaines et des contextes de son utilisation. Pour Dupuy (1984), l'une des premières propositions de définition formelle d'un tel objet urbain est celle d'un réseau technique urbain, qui est défini comme un équipement technique de solidarité urbaine. Landau & Diab (2017) enrichissent cette première définition en y ajoutant une vision urbanistique (l'expansion des réseaux) et technique (le matériel et la structure des réseaux), permettant de considérer les réseaux urbains comme un système sociotechnique en deux dimensions: organisationnelle et technique.

On peut alors définir un réseau technique urbain comme un réseau d'infrastructures essentielles et linéaires interconnectées qui facilitent le transport de flux, dans le but de garantir le bon déroulement d'un service urbain. Plus précisément, nous employons le concept de « réseau technique urbain » pour désigner les équipements techniques qui fournissent les services urbains de transport des biens et des personnes (réseaux routiers), de transport des eaux (réseaux d'alimentation en eau potable et d'assainissement), de transport d'énergie (réseaux d'électricité) et, enfin, de télécommunications (Dabaj, 2021).

Au cours de la dernière décennie, un nombre croissant de catastrophes naturelles ont eu des répercussions négatives sur les économies régionales de même que sur la vie des millions de personnes. En ce qui concerne les villes d'Afrique de l'Ouest, elles sont devenues plus vulnérables en raison de l'augmentation du taux de migration urbaine d'une part, et d'autre part, à cause d'une concentration d'actifs de grande valeur et d'opérations gouvernementales et commerciales. Par exemple, beaucoup de villes à l'image du Grand Lomé (Togo) sont situées dans des zones côtières et d'autres zones naturellement vulnérables aux catastrophes majeures. Ainsi, le potentiel d'impacts graves et étendus des événements extrêmes n'a jamais été aussi grand qu'aujourd'hui.

Le cinquième rapport d'évaluation du Groupe d'Experts Intergouvernemental sur l'Évolution du Climat (GIEC, 2014) mettait déjà les Etats en garde contre l'augmentation des impacts potentiels sur les systèmes d'infrastructure, l'environnement bâti et les services écosystémiques dans les zones urbaines. Cette mise en garde était le résultat de l'évolution des risques climatiques, et une croissance galopante du taux d'urbanisme. Certains auteurs tels que Cantuarias-Villessuzanne *et al.* (2021), Pinson *et al.* (2019), Rankovic *et al.* (2012) ont fait le même constat en ce qui concerne le potentiel de défaillances en cascade. Sourisseau *et al.* (2020) note qu'en ce qui concerne le cas spécifique du Togo, « le taux d'urbanisation a connu une forte augmentation, passant de 9,4% en 1961 à 37,7% en 2010 ». Dès lors, il convient de trouver des stratégies de durabilités et de survivabilité pour les systèmes qui manifestent une interconnexion à toutes les échelles. Si à la base la théorie de la survivabilité des systèmes faisait référence à la théorie de la continuité des activités appliquée à la fourniture d'un service particulier, cette approche est désormais utilisée par tous les opérateurs de services urbains performants. Ainsi, les opérateurs togolais ne dérogent pas à cette règle. L'objectif étant de garantir la continuité des services, et d'assurer une bonne gestion de l'information.

1.1. Villes et réseaux

Selon Musa (2017), l'infrastructure d'une ville comprend des systèmes complexes (tels que les postes transformateurs du réseau électrique, les stations d'épuration des eaux usées, les réseaux d'adduction d'eau potable, les services d'incendie, les services publics, les écoles, les bibliothèques, les entreprises, les maisons), associés à une infrastructure urbaine complexe facilitant ainsi l'interaction des citoyens et l'intégration technologique de l'infrastructure de la ville.

La complexité d'une chose se caractérise par sa capacité à être perçue selon des perspectives multiples et souvent contradictoires. Ce n'est qu'une approche pour caractériser les villes comme des systèmes complexes (Dong, 2023). Les villes peuvent être aussi petites qu'un kilomètre carré ou aussi grandes que de nombreux pays plus petits; croître et changer au fil du temps; être à la fois réelles et virtuelles; se trouver n'importe où; être des réseaux; être spatiales et transcendantes; concerner des lieux et des personnes; être aussi grandes que de nombreuses petites nations (Zhao et Fang, 2018).

Ainsi, la ville intelligente adopte un système urbain intelligent afin d'atteindre une croissance économique et un développement durable. Dans une telle perspective, la collecte de données est essentielle pour garantir l'efficacité, ce qui conduit à l'optimisation des systèmes. L'objectif étant de fournir des solutions technologiques aux différents besoins et embarras de la ville et d'améliorer les conditions de vie des populations qui habitent la ville. Cependant, force est de noter que l'amélioration ne doit pas seulement concerner le niveau de vie des populations. Elle doit également permettre de réduire, par exemple, les embouteillages tout en établissant un cadre propice pour les affaires.

Cela signifie donc que l'expansion et la dépendance des villes aux réseaux techniques urbains entraînent une forme d'urbanisation appelée « réticulaire » (Dupuy, 1991). Par conséquent, l'organisation des réseaux ne se limite pas à celle d'un système technique, mais elle conduit à l'organisation d'un espace selon ses fonctionnements. Selon Serre *et al.* (2016), cette forme d'urbanisation contribue à la propagation du risque d'inondation en milieu urbain.

Au Togo par exemple, selon l'Agence Française de Développement (AFD), les grandes inondations qui se sont produites en 2008, 2010 et 2022 étaient dues en grande partie à l'insuffisance d'infrastructures de drainage des eaux de pluie et du système de gestion des déchets solides. Ce qui avait notamment engendré de nombreux préjudices (notamment matériels et humains) comme l'inaccessibilité des routes, destruction des ponts, la dégradation des canalisations, etc. Les autres secteurs d'activité économique avaient également été fragilisés à cause de l'inaccessibilité des réseaux urbains et le manque à gagner est à relever auprès des travailleurs du secteur formel et informel. Force est de noter qu'en 1984, Marguerat (1984), dans ses écrits « L'armature Urbaine du Togo », notait que le « Togo s'apparentait plus au schéma macrocéphale qu'à un réseau harmonieusement équilibré ».

Notre étude porte particulièrement sur le Grand Lomé. Il ressort que les infrastructures essentielles telles que les télécommunications, la production et la transmission d'électricité, les transports, le réseau des eaux usées, les systèmes d'approvisionnement en eau et les services d'urgence sont devenus des composants d'un système interconnecté plus vaste dans cette région. De ce fait, la perturbation d'une infrastructure se répercute inexorablement sur d'autres infrastructures et finit par avoir un impact sur la communauté et l'économie. Cependant, il convient de noter que la nature et la portée des impacts dépendent de la nature de la catastrophe, ainsi que du type et du mode de défaillance primaire d'un élément ou du système d'infrastructure; ce qui entraîne inexorablement l'effet « domino » des défaillances dans d'autres systèmes. C'est à dire qu'il existe une grande interdépendance entre les infrastructures dans le Grand Lomé.

Il convient de rappeler qu'en 2022 les inondations avaient touché une grande partie de Lomé (dont 20 à 35% des zones habituellement non-inondables). Cette inondation concernait principalement la zone des deux cordons (la basse ville de Lomé entre la lagune et la mer) et l'aréal où résident 40 à 50% de la population. Des examens et études ont révélé que cette inondation était due à l'emplacement très bas de la ville par rapport au niveau de la mer, la hausse du niveau de la mer, les changements climatiques (augmentation des précipitations), l'urbanisation accélérée, la construction dans les lits majeurs des cours d'eau (vallée du Zio), l'imperméabilité des sols due aux dépotoirs et aux déchets plastiques, etc. Les conséquences étaient manifestes notamment sur les infrastructures urbaines, l'accès aux services urbains et le développement socio-économique. Toute cette situation nécessite donc des mesures urgentes et à moyen terme.

La présente étude vise à modéliser l'interdépendance entre les réseaux techniques urbains dans le Grand Lomé afin de mieux cerner la propagation de la vulnérabilité par effets domino lors des inondations urbaines et d'améliorer les politiques de résilience urbaine. Nous utilisons le graphique multiplex pour modéliser les réseaux techniques urbains dans le Grand Lomé. Cependant, la question qui se pose est celle de savoir combien de couches sont effectivement nécessaires pour modéliser avec précision les réseaux techniques urbains du Grand Lomé ? La suite de cette étude apportera une réponse à cette question.

2. MÉTHODOLOGIE

2.1. Zone d'étude

Lomé, la capitale du Togo, est située dans la région maritime, l'une des cinq (5) régions administratives du Togo. A sa création, la commune de Lomé était enclavée entre la lagune au nord, l'océan Atlantique au sud, le village de Bè à l'est et la frontière d'Aflao à l'ouest. En 2010, elle était délimitée par le Groupement Togolais d'Assurances (GTA) au nord, l'océan Atlantique au sud, la raffinerie de pétrole à l'est et la frontière Togo-Ghana à l'ouest. L'agglomération s'étend sur une superficie de 333 km^2, dont 30 km^2 dans la zone lagunaire, avec une population de 1 477 660 habitants. La Figure 1 montre la situation géographique de la ville de Lomé. En 2022, la population de la ville est passée à 2 188 376 habitants sur une superficie de 425,6 km^2.

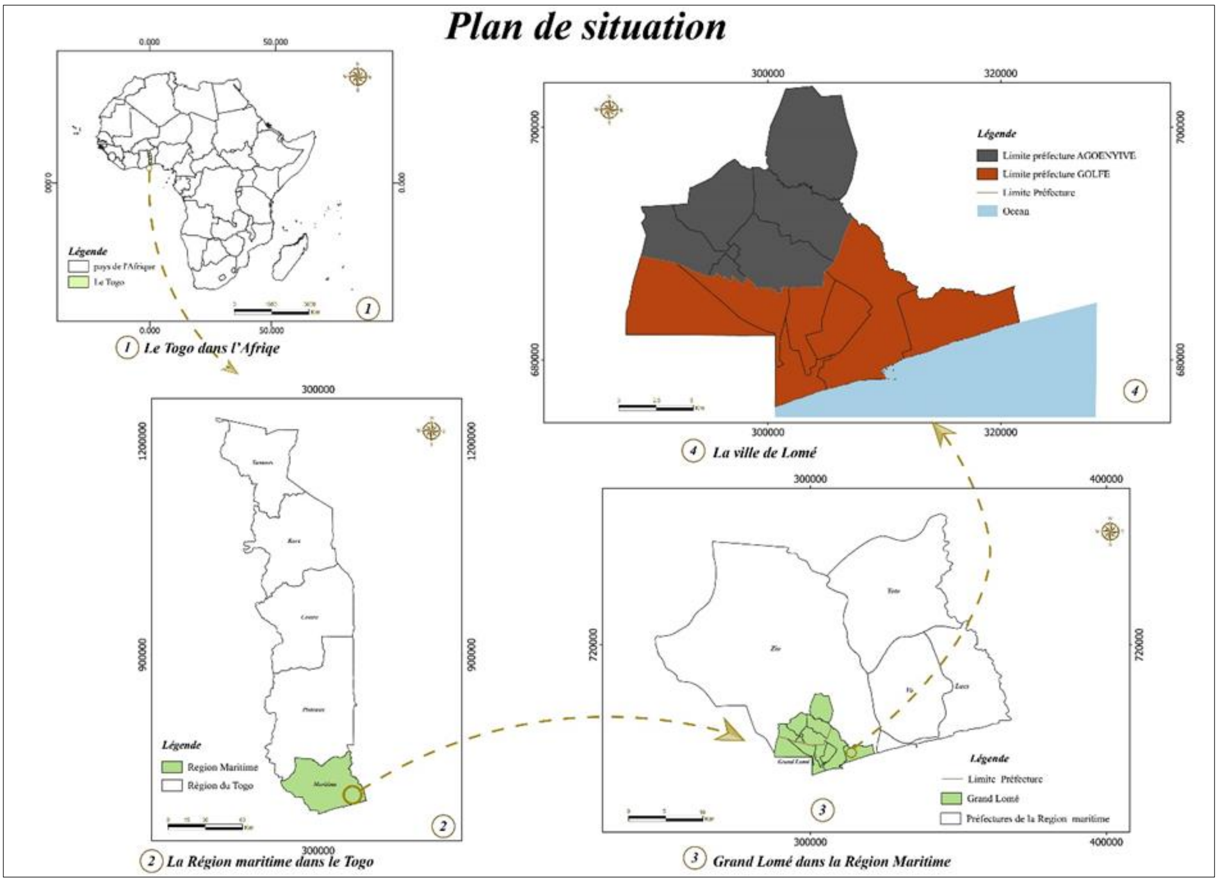

Fig. 1 – Plan de situation de Lomé.
Source: Attipo, 2023.

2.2. Les inondations à Lomé

Depuis 2010, les saisons de pluies ont été très pluvieuses au Togo. Les pluies diluviennes ont entraîné des dégâts matériels importants et des pertes en vies humaines. Elles ont été accompagnées de vents violents et ont causé souvent des inondations dont l'ampleur varie d'une zone à une autre. Cette pluviométrie au-dessus de la normale est également à l'origine de crues exceptionnelles des principaux cours d'eau, notamment la rivière Zio et les différentes lagunes de la ville. Ainsi, à la faveur de certains facteurs de vulnérabilité aux inondations et à la remontée de la nappe phréatique, il en est résulté une inondation entre juin et octobre 2013 dans les milieux susmentionnés, suscitant une mobilisation prompte du gouvernement et de ses partenaires. La Figure 2 nous présente les zones vulnérables aux inondations de la ville de Lomé. La pluviométrie du mois de juin 2013 avait atteint une hauteur de 365,1 mm contre une moyenne normale de 184,4 mm sur une période de 30 ans allant de 1971 à 2000. Pour le mois de septembre 2013, la ville de Lomé avait enregistré 205 mm d'eau contre une normale de 64 mm soit, 314% d'excédent (ANPC, 2017). Aujourd'hui, malgré une multitude des bassins de rétention construites dans la ville pour collecter les volumes d'eaux pluviales, plusieurs quartiers sont toujours affectés par des inondations même étant éloignés des zones de dépressions. La Figure 3 nous présente les différents bassins et les zones de dépression dans le Grand Lomé. Elle permet de visualiser les zones les plus vulnérables aux inondations et autres risques liés à l'eau. En comprenant la répartition de ses bassins et dépressions, il est possible de mieux planifier les infrastructures et les mesures de prévention pour minimiser les impacts des catastrophes naturelles dans ces zones critiques, comme les inondations.

Les inondations ont été extrêmement graves, causant des pertes et dommages considérables aux biens, aux infrastructures et aux personnes comme le décrit le tableau ci-dessous (Tableau 1). Le tableau ci-dessous montre les causes des inondations en passant par la superficie touchée jusqu'aux pertes et dommages causés par les inondations en 2010. Le tableau donne une description synthétique des inondations de 2010 au Togo.

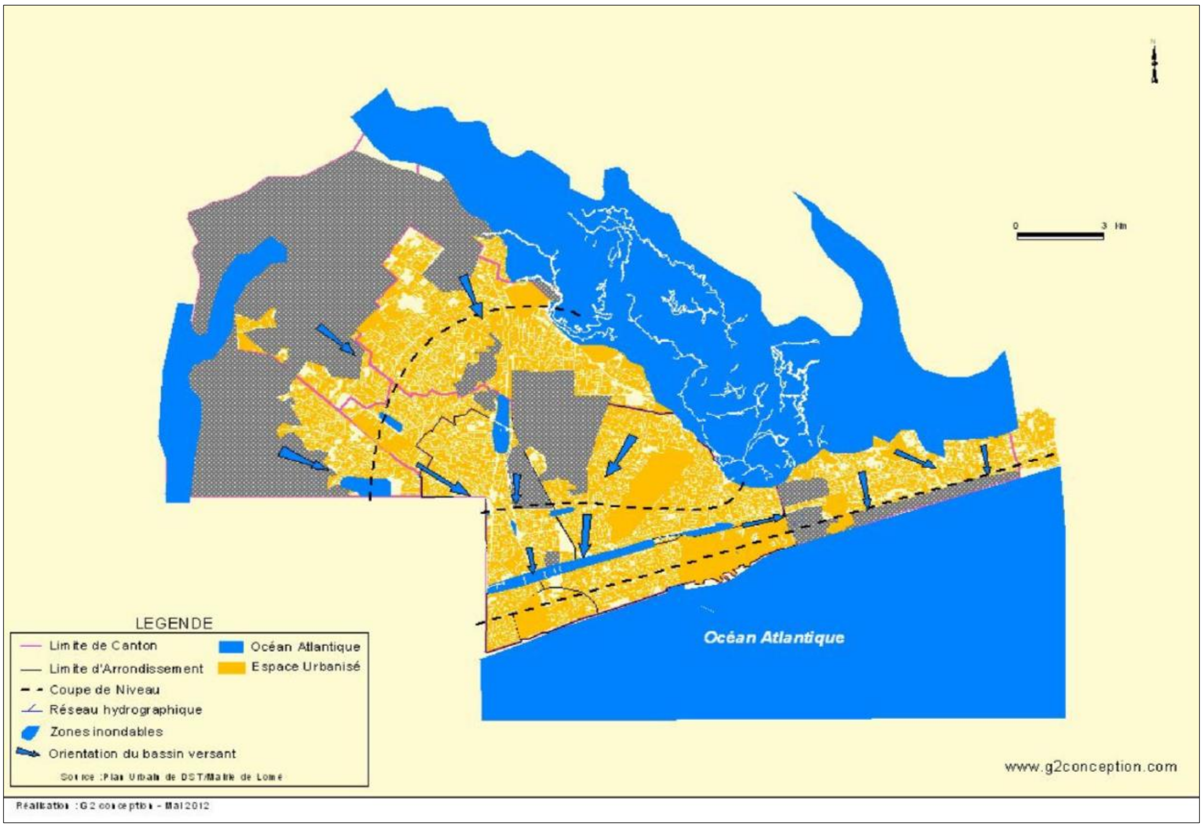

Fig. 2 – Carte des zones inondables de Lomé.
Source: SDU Grand Lomé.

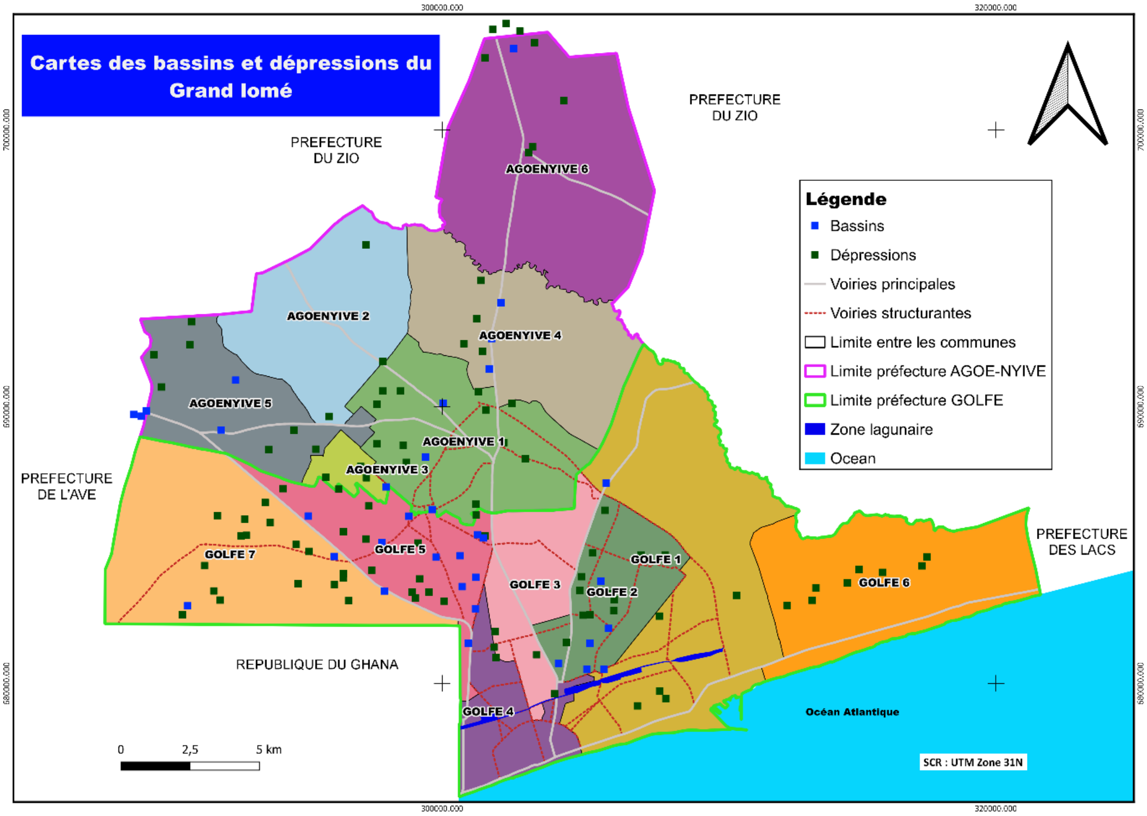

Fig. 3 – Les bassins et dépressions du Grand Lomé.
Source: ANPC 2022.

Tableau 1

Description des inondations de 2010 au Togo

Causes premières	Fortes pluies
Ampleur des inondations (1 à 3)[1]	3 (élevée)
Classes de gravité (1 à 4)[2]	3 (élevée)
Superficie de la zone touché (km^2)	195
Durées (jours)	20
Personnes touchées	82 767
Dommages sur les infrastructures	3 (élevée)
Décès enregistrés	21

Source: PDNA, 2012.

2.3. Analyse des interdépendances

Le cadre proposé pour la résilience par interdépendance fonctionnelle entre les réseaux techniques urbains dans le Grand Lomé est basé sur l'analyse des modes de défaillance et leurs effets. Cette étape nous permet d'étudier la séquence et le type d'effets en cascade potentiels causés par les dysfonctionnements. Une analyse dynamique, ou un examen de la manière dont le système pourrait évoluer au fil du temps, est également nécessaire pour découvrir et comprendre les interdépendances

[1] Ampleur: 1 – faible; 2 – moyenne; 3 – élevée
[2] Classe de gravité: 1 – faible; 2 – moyennes; 3 – élevée; 4 – exceptionnelle.

temporelles (Gürsan et de Gooyert, 2020). Les dysfonctionnements en cascade ou effets en cascade peuvent être définis comme l'ensemble des événements dans les sous-systèmes humains qui provoquent des perturbations physiques, sociales ou économiques liées à un événement physique ou à la mise en place d'une défaillance technologique ou humaine initiale. Dans le cadre de cette recherche, un dysfonctionnement en cascade se produit lorsqu'une perturbation fonctionnelle d'une infrastructure entraîne la défaillance d'un composant dans une deuxième infrastructure, ce qui provoque ensuite une perturbation fonctionnelle dans la deuxième infrastructure.

Afin de mieux appréhender des dysfonctionnements en cascade dus à différentes causes (événements originaux ou non), trois types de dysfonctionnements sont définis dans cette recherche: (a) dysfonctionnement direct: les composants perdent leur fonction en raison du danger initial; (b) dysfonctionnement interne indirect: les composants perdent leur fonction en raison de la défaillance d'un composant à l'intérieur du même sous-système; (c) et dysfonctionnement externe indirect: les composants perdent leur fonction en raison de la défaillance d'un composant extérieur au même sous-système. La séquence des événements peut nous permettre de comprendre la cause et l'effet de chaque événement de dysfonctionnement, et de comprendre les systèmes directement et indirectement affectés sous différents aléas. Ainsi, une explication est apportée par cette étude sur comment utiliser les résultats obtenus pour améliorer la résilience des réseaux techniques urbains à Lomé.

Ainsi, la méthodologie se focalise sur quatre (04) points essentiels comme le résume de la Figure 4 ci-dessous. Il s'agit principalement de l'analyse du fonctionnement des réseaux techniques, des relations fonctionnelles entre ces derniers afin de mieux comprendre les connexions et les interconnexions, et tout autres relations possibles entre ses systèmes sociotechniques. Après cela, nous allons identifier des éventuelles défaillances sur les réseaux et la propagation des défaillances entre les réseaux dépendants ou interdépendants afin de classifier les déférentes relations entre ces réseaux et, enfin, de modéliser leurs interdépendances.

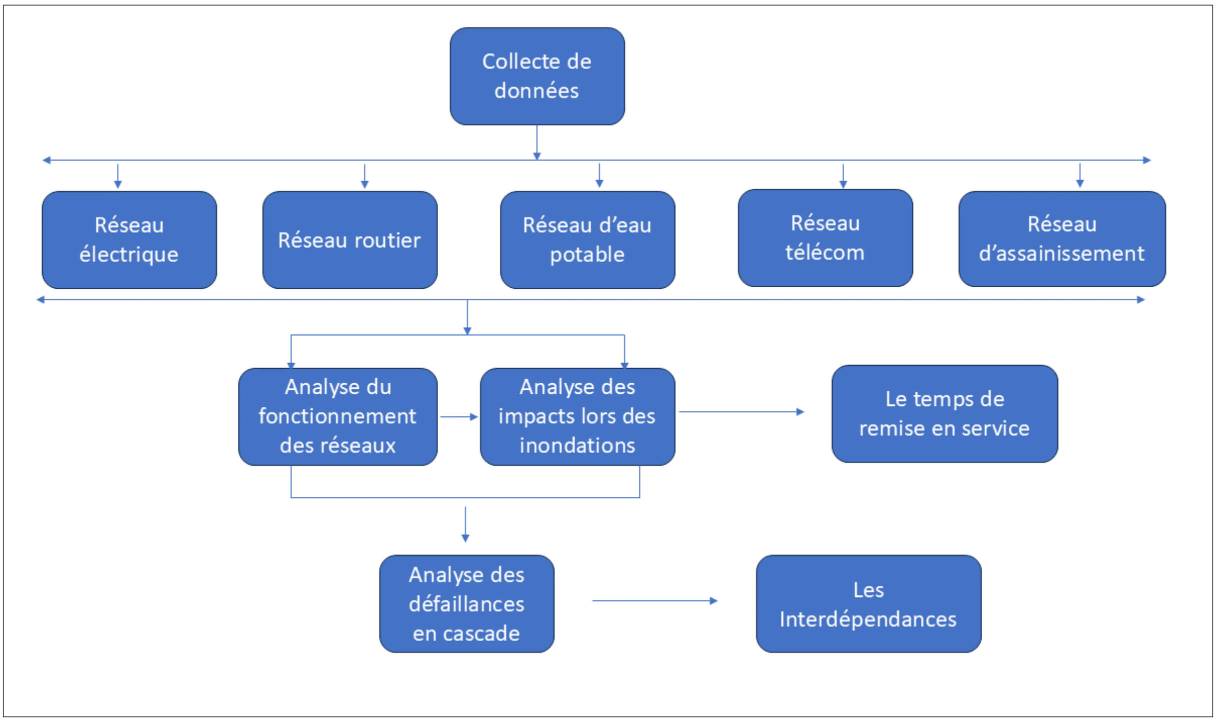

Fig. 4 – Schéma méthodologique.

Tous les grands réseaux techniques urbains – électricité, eau potable, autoroutes, télécommunications, assainissement – ont été examinés afin d'en étudier les interdépendances. L'inventaire exhaustif nécessaire à l'approche choisie a été réalisé à partir de diverses sources: annonces de presse, études, bulletins d'information, flux d'actualités et rapports provenant des sites web des autorités locales de Lomé et des fournisseurs de réseaux ont été autant de sources à partir desquelles des données qualitatives et quantitatives ont été collectées.

Cette méthodologie a permis d'examiner les défaillances en cascade pendant les inondations et les premières étapes de la reprise afin d'identifier les interdépendances des infrastructures critiques. Les défaillances en cascade ont été examinées à l'aide d'observations sur place et de faits vérifiés, mettant en évidence les interdépendances existantes et leurs fonctions au cours de l'intervention et de la remise en service.

3. RÉSULTATS ET DISCUSSIONS

Il ressort que les réseaux, les infrastructures et les composants de la ville de Lomé sont vulnérables aux inondations. Ce qui implique qu'ils auront des répercussions et des impacts sur leurs propres réseaux. L'évaluation de la criticité des infrastructures permet de prioriser les actions à entreprendre pour minimiser les interruptions de service. Cette évaluation est basée sur certains critères, notamment la dépendance des réseaux les uns par rapport aux autres, en temps normal que pendant les inondations. La notion de criticité est étroitement liée à l'endommagement du réseau, l'infrastructure et les composants (selon le niveau de détail) après une inondation. Les valeurs de criticité peuvent changer au cours des événements en fonction du niveau d'eau. Par exemple, afin d'identifier les stratégies de reconstruction du réseau urbain de Lomé après une inondation, différentes contraintes doivent être prises en compte, notamment en termes de ressources, de temps et de matériaux. Ainsi, il pourrait prendre des jours, voire des mois, pour que les réseaux touchés retrouvent un fonctionnement normal. Une mauvaise prise en compte de ce risque d'impacts sur les réseaux peut conduire à un délai supplémentaire important avant le retour à la normale.

3.1. Les réseaux techniques: des infrastructures essentielles

Le fonctionnement des villes dépend en grande partie du fonctionnement des réseaux considérés comme la colonne vertébrale. La Figure 5 montre l'ensemble des réseaux techniques urbains étudiés sur les bassins et les dépressions du Grand Lomé. La plus petite défaillance pourrait avoir des conséquences en cascade sur le fonctionnement urbain (Robert *et al*., 2009a). Par exemple, plusieurs équipements urbains du Grand Lomé (écoles, marchés, dispensaire) sont restés inaccessibles pendant plusieurs jours suite à l'impraticabilité de la route d'Avenou lors des inondations de 2010. Un autre exemple est le cas de l'Allemagne, l'Afrique du Sud, l'Italie et la Roumanie qui ont connu une panne du réseau internet suite à l'effondrement du World Trader Center en 2001 à New York (Serre *et al*., 2016).

Pour Serre *et al.,* (2016) et Robert *et al.,* (2009), ces types de défaillance des réseaux techniques urbains dits essentiels et leurs effets montrent la sensibilité des réseaux à tout type d'aléas tels que les aléas technologiques et naturels, l'erreur humaine, les attentats, etc. Selon Serre *et al.* (2016), les réseaux techniques urbains doivent être rendus plus sûrs pour éviter ces types de défaillances. Mais, du fait de l'enchevêtrement des réseaux, leur extension tentaculaire et extrême concentration de certains nœuds, augmenter la résilience des réseaux reste un très grand défi. En effet, l'interconnexion et l'interdépendance de l'ensemble de ces réseaux ont abouti à la création d'un macro-réseau reliant le monde entier (Serre *et al.,* 2016).

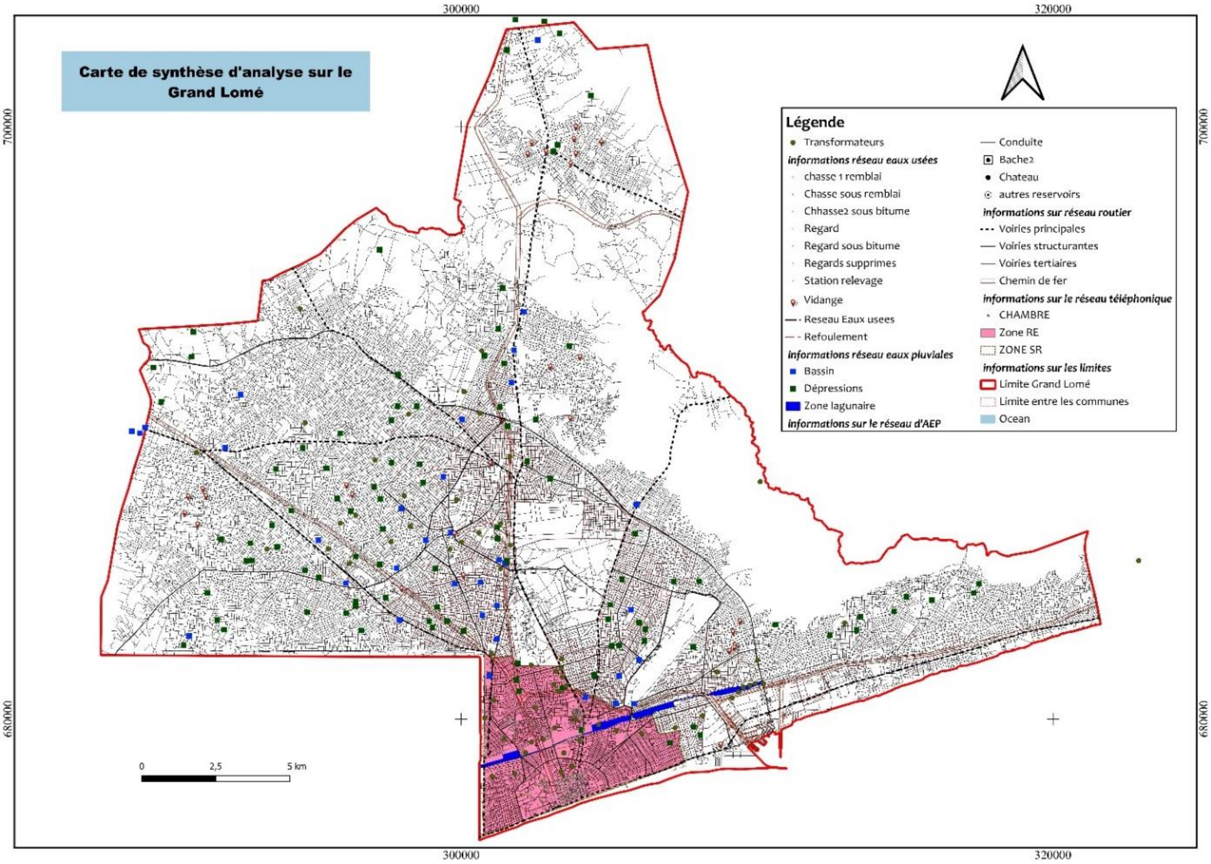

Fig. 5 – Carte de synthèse d’analyse des réseaux techniques urbains du Grand Lomé.

La Figure 5 présente les différents réseaux techniques urbains dans le Grand Lomé, incluant les infrastructures électriques, les réseaux d’adduction d’eau et les systèmes de transport. Elle montre également les zones vulnérables aux inondations.

3.2. L’effet domino sur les réseaux urbains

Les événements de dysfonctionnements externes sont essentiels à notre étude, car il est bien documenté que la défaillance d’un système affecte la performance des autres systèmes. Les systèmes d’infrastructures critiques (IC) ont été continuellement exposés à de multiples menaces et dangers (Kröger et Nan, 2014). Selon Kröger (2019), « une défaillance unique au sein d’un système d’infrastructure ou même la perte de son service continu peut être suffisamment dommageable pour notre société et notre économie, tandis que des défaillances en cascade traversant des sous-systèmes et/ou même des frontières peuvent entraîner des effondrements multi-infrastructures et des conséquences sans précédent ».

L’ampleur des effets en cascade peut être influencée par la force de la connexion. Le phénomène connu sous le nom d’« effet de cascade » décrit comment les résultats ou les effets particuliers du franchissement d’un seuil se répercutent en cascade sur plusieurs échelles, périodes et/ou systèmes entiers. Parce qu’ils sont moins adaptatifs et plus résistants aux niveaux courants de volatilité externe, les systèmes fortement couplés sont plus enclins à subir des effets en cascade (Wang *et al.*, 2023).

L’importance de prévenir ou, du moins, de minimiser l’impact négatif des défaillances en cascade dues aux interdépendances entre les systèmes a été reconnue, non seulement par les gouvernements, mais aussi par le public, comme un sujet de protection des infrastructures critiques. L’objectif de la protection n'est pas seulement d'identifier la cause des défaillances et de les prévenir, mais aussi d'arrêter les événements en cascade ou en escalade pouvant affecter d'autres infrastructures (Rey-Thibault *et al.,* 2023). Dans le cadre de la présente étude, l'objectif était de bien comprendre ces problèmes d'interdépendance souvent cachés et les cascades de défaillances potentielles, et de les aborder à l'aide de techniques de modélisation et de simulation avancées.

D'une manière générale, il ressort des résultats, qu'une prise en compte de l'importance des interdépendances entre les systèmes d'infrastructure et des incertitudes liées à leurs interactions constitue un défi pour le Grand Lomé, en raison de la complexité et de la nature perpétuelle de ces systèmes, de l'absence d'informations suffisantes caractérisant clairement la propagation des défaillances et du manque d'outils de modélisation/simulation permettant d'analyser de manière exhaustive les interactions entre les systèmes. L'ordre des événements peut nous aider à comprendre les causes et les effets de chaque dysfonctionnement, ainsi que les systèmes directement et indirectement touchés lorsque divers dangers sont présents. En somme, en ce qui concerne les résiliences sociaux-infrastructurelles, deux scénarios peuvent se produire: soit les dangers influencent les systèmes sociaux et leurs dysfonctionnements affectent les systèmes d'infrastructure, soit les dangers affectent les systèmes d'infrastructure et leurs dysfonctionnements affectent les systèmes sociaux.

3.3. Interdépendances entre les réseaux techniques

L'étude se base sur l'interdépendance fonctionnelle des systèmes sociaux-infrastructurels urbains en examinant la relation entre l'infrastructure routière et le service médical d'urgence. Yang *et al.* (2022) montrent que la dépendance et l'interdépendance sont des termes utilisés dans le contexte de la résilience urbaine pour décrire la manière dont un sous-système urbain influence ou est influencé de manière significative par un autre sous-système urbain.

Les réseaux techniques apparaissent rarement de manière isolée. Par exemple, une inondation provoquant l'inondation d'un transformateur électrique perturbe le réseau électrique, engendrant alors de nombreuses coupures d'électricité. Ces coupures créent des perturbations sur certaines parties du réseau d'eau potable. Ces incidences peuvent s'étendre jusqu'aux pompes de relevage, les feux tricolores (entrainant ainsi une perturbation du Trafic) et le réseau de télécommunication (Huet *et al.,* 2003; Ruin, 2007).

Dans le cas précis des réseaux de transport, la manière dont un réseau affecte un autre n'est pas triviale et souvent, des points spécifiques d'un réseau interagissent avec des points spécifiques d'un autre réseau. Cela conduit au concept de réseaux interactifs dans lesquels des liens existent entre les points d'un même réseau ainsi qu'entre les réseaux. Tout comme les gaz qui, par définition, sont constitués de particules non-interactives, le comportement des réseaux en interaction présente des propriétés émergentes profondes qui n'existent pas dans les réseaux individuels.

La propriété fondamentale qui caractérise les réseaux interdépendants est l'existence de deux types de liens qualitativement différents: les liens de connectivité et les liens de dépendance. Les liens de connectivité sont les liens que nous connaissons bien dans la théorie des réseaux simples, car ils relient les points d'un même réseau (Caillaud, 2022). Ils représentent généralement la capacité d'une certaine quantité (information, électricité, trafic, flux, etc.) à circuler d'un point à l'autre.

Sur la base de l'analyse des réseaux techniques dans le Grand Lomé et de plusieurs travaux répertoriés dont celui de Bocquentin (2020), nous catégorisons les interdépendances en trois (03) éléments que nous illustrerons par des exemples simples: (a) les infrastructures A et B sont physiquement interdépendantes; par exemple, la capacité de l'infrastructure B à fournir de l'eau potable dépend de la capacité de l'infrastructure A à lui fournir de l'énergie. On parle de l'interdépendance physique; (b) l'interdépendance cybernétique: le fonctionnement de l'infrastructure A dépend des informations que l'infrastructure B transmet par l'intermédiaire d'un système d'information (à l'instar d'un feu de circulation qui dépend de ses contrôleurs centralisés); (c) (Inter)dépendance géographique: en raison de leur proximité, les infrastructures A et B sont affectées par l'état de l'un et de l'autre. Par exemple, l'état d'un câble électrique enterré dépend de l'état de la route sur laquelle il est installé, nous pouvons l'observer avec la Figure 6 modélisé par le Centre européen de prévention des risques d'inondation. Il faut garder à l'esprit que ces dépendances sont uniquement des liens physiques et ne sont pas fonctionnelles, comme le présente Lhomme (2012) sur les relations entre réseaux techniques urbains (Fig. 7).

Fig. 6 – Modélisation des interdépendances (CEPRI 2016).

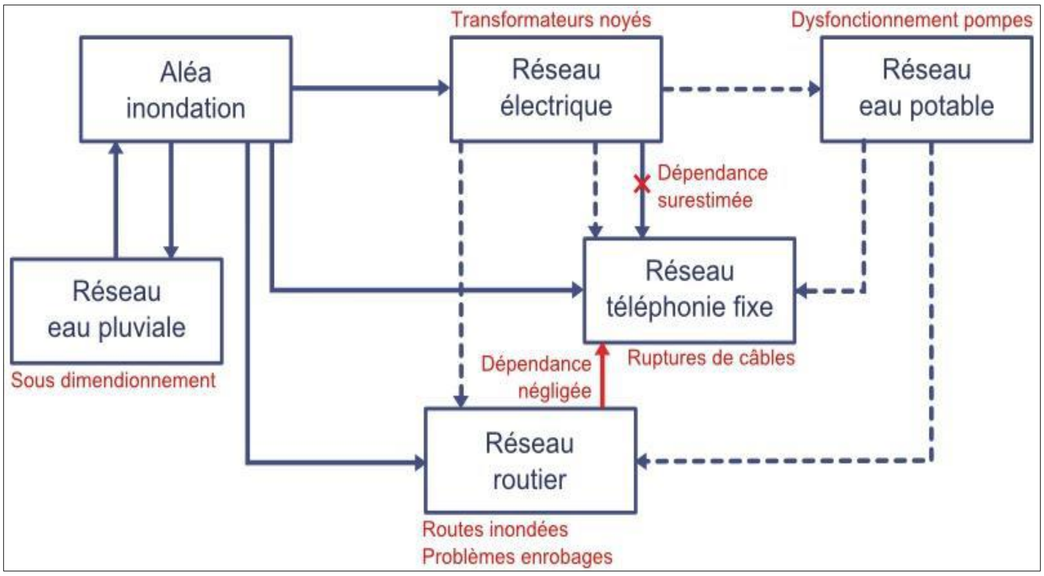

Fig. 7 – Modélisation de l'interdépendance entre les réseaux techniques urbains (Lhomme, 2012).

À cause du fait qu'elles peuvent constituer un danger et altérer la fonctionnalité d'une ou plusieurs infrastructures ou systèmes, les (inter)dépendances, en tant que phénomènes complexes, servent finalement de multiplicateurs de risques (Petit et Verner, 2016). Les effets des dysfonctionnements et des défaillances, ou des modifications de la capacité d'un système à remplir ses fonctions, peuvent alors aller bien au-delà des domaines et des systèmes qui ont été touchés en premier lieu. (Bocquentin *et al.*, 2020).

Les figures ci-dessus (6 et 7) mettent en évidence les interdépendances entre les différents réseaux techniques, montrant comment une défaillance dans un réseau peut affecter les autres. Les effets en cascade illustrés soulignent l'importance de renforcer la résilience de chaque réseau pour prévenir des perturbations généralisées en cas de catastrophe. En comprenant ces interdépendances, il est possible de mieux planifier et de prioriser les interventions pour minimiser les impacts négatifs sur l'ensemble des infrastructures urbaines (Touili, 2022).

En somme, l'application potentielle de l'étude à l'analyse de la résilience interdépendante de plus de deux sous-systèmes urbains est une autre caractéristique qui mérite attention. Cette méthode peut être utilisée pour trouver les dépendances fonctionnelles de nombreux systèmes puisque les dépendances fonctionnelles entre deux systèmes sont identifiables. Néanmoins, l'augmentation de la quantité et de la complexité des interférences rendrait plus difficile l'analyse des dysfonctionnements en cascade et l'adaptation à des modes améliorés. Toutefois, cette idée doit être considérée comme une avancée positive dans l'étude de la résilience urbaine.

5. CONCLUSIONS

Cette recherche est partie sur le postulat que l'analyse de interdépendances entre les réseaux techniques urbains est essentielle pour l'implémentation des stratégies de résilience urbaine face aux inondations en particulier, et de développement urbain durable de manière globale. Ensuite, elle s'est fixée comme objectif. Cette étude a analysé les dysfonctionnements en cascade et les modes de défaillance pour évaluer les effets potentiels dus aux dangers en vue de modéliser les relations entres les différents réseaux. Ainsi, l'étude a été faite sur la base de scénario supposé afin d'identifier la séquence des défaillances des composants et de clarifier les causes et les conséquences. De plus, les modes de défaillance de chaque composant affecté ont également été identifiés. Comme résultat, une interdépendance des sous-systèmes sociaux-infrastructurels-urbains est démontrée en trois styles: l'interdépendance physique, cybernétique et enfin géographique. L'observation continue du développement de l'événement de catastrophe du point de vue de la fonction de défaillance en cascade aide à mieux comprendre l'interdépendance des systèmes et, finalement, à mieux gérer le sous-système urbain. L'ampleur des perturbations est influencée par les relations entre les réseaux, étant donné que les réseaux apparaissent rarement de manière isolée. En raison de la complexité des réseaux lors des interactions et des incertitudes, la prise en compte des interdépendances reste un défi majeur. Il sied de souligner que la méthodologie proposée peut être appliquée à n'importe quel sous-système des zones urbaines (systèmes organisationnels-gouvernementaux et systèmes de flux nature-énergie) pour tous les types de risques. Inévitablement, il y aura des acteurs, des fonctions, des modes de défaillance et des modes d'amélioration différents. Par conséquent, cette méthodologie peut aider les décideurs dans la gestion des urgences et peut être adaptée au contexte local afin d'assurer la continuité des services urbains lors des inondations ou faire refonctionner dans un délai très court les services après un dysfonctionnement suite aux inondations. Tout cela arriverait car le constat et les effets urbains en cascade dans plusieurs domaines pourraient dépasser les limites temporelles et spatiales du danger initial en raison de l'interdépendance fonctionnelle entre les réseaux techniques urbains dans le Grand Lomé. La résilience urbaine dépend directement de l'interdépendance fonctionnelle des réseaux techniques.

Le développement urbain durable soulève une problématique plus générale qui dépasse le cadre de cette recherche: dans le futur, quels acteurs devront être en charge de la gestion de l'urbanisation des réseaux techniques ? Comment planifier l'expansion des systèmes urbains face aux changements climatiques ? En effet, de la manière dont on planifie la ville, avec les effets pervers des changements climatiques en milieu urbain, il semble indispensable de maîtriser le développement des réseaux techniques essentiels afin d'appréhender leurs contributions aux stratégies de résilience et de la durabilité urbaine.

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THE DEVELOPMENT OF BOGOR CITY: A SECONDARY CITY WITHIN THE FAST-GROWING GREATER JAKARTA

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Key-words: Kota Bogor, secondary city, Greater Jakarta, territorial, and regional development.

Abstract. Bogor is the smallest major city in the Greater Jakarta Area, with only a third of the population compared to other cities in the region. Located in a mountainous area just south of Jakarta, Bogor's rich historical heritage has turned it into a thriving tourist destination – one of the city's primary functions. Meanwhile, Jakarta's rapid expansion as Indonesia's primate city has accelerated over the past thirty years, further solidifying its central role in relation to the surrounding areas, including Bogor. To support this central function, various public facilities have been developed, particularly in land transportation to cities around Jakarta. Given these developments, can Bogor continue to thrive sustainably in its two main functions? Will these functions evolve due to factors arising from the Greater Jakarta Area development project? This research is based on a case study over time and space, which focuses on Bogor City as a single case in a specific location over a series of time periods. The study's findings show that Bogor can continue to sustain its key functions, particularly in historical tourism and agriculture, as demonstrated by a 5% growth in income from sectors related to these areas.

1. INTRODUCTION

The development of secondary cities – urban centres smaller than primary cities but still significant in their regional context – is critical for promoting balanced economic growth and reducing pressure on megacities. By fostering growth in these areas, countries can alleviate congestion, reduce housing shortages, and enhance living standards in larger metropolitan areas, which often face infrastructure strain due to rapid urbanization. Moreover, secondary cities play a key role in facilitating regional development by creating employment opportunities, promoting decentralized industrialization, and improving the distribution of public services. They are increasingly recognized as important centres for examining the growing disparities among cities in rapidly developing economies (Shores *et al.*, 2019; Videla *et al.*, 2020). They also act as hubs for rural-urban links, connecting smaller towns and rural areas to global markets (Roberts, 2014; UN-Habitat, 2020). However, secondary cities often receive lower levels of investment in infrastructure and support services compared to larger metropolitan regions (Roberts, 2014, 2019; Videla *et al.*, 2020). This means that while larger metropolitan areas tend to attract more attention and resources due to their population size and economic influence, secondary cities are frequently overlooked, suffering from an outdated infrastructure, inadequate public services, and fewer opportunities to foster innovation or attract external investment.

Secondary cities are no longer characterized by their population size. Instead, they are now defined by their functionality and their connections to global and national urban networks. Furthermore, defining secondary cities based on a hierarchical classification of cities according to population size is no longer a major concern. Instead, greater attention is now given to a city's functionality and its relationships with national, regional, and global trade networks, knowledge systems, competitiveness, and investment

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(Roberts, 2014). These factors have a significant impact on a city's status and role within the national and global urban system. Moreover, the growing influence of artificial intelligence and all-electronic information systems is shaping the dynamics of urban development more and more. These developments are also evident in Asian and Southeast Asian cities, including those in Indonesia (Roberts, 2014; Joo and Tan, 2020; ASEAN, 2022).

From a geographical perspective, secondary cities are defined as urban areas with formal administrative boundaries that serve as centres for management, logistics, and production at the sub-national or metropolitan sub-region level within a country's urban system. These cities provide various services essential for the basic needs of their populations, including health care, education, housing, and other crucial social services. Generally, secondary cities play a broader role and function within their geographical regions. The population of secondary cities typically accounts for around 10-50% of the total population of surrounding major cities, though some may have smaller proportions (Roberts, 2014).

Secondary cities can be categorized into three characteristic groups. The first group is *dynamic secondary cities*. These cities experience strong local economic growth and have a dynamic relationship with national and international activity centres. They are part of a competitive trade system with a focus on export strength and outward orientation. Examples include Denpasar (Bali, Indonesia) and Durban (South Africa). The second group includes *moderately growing secondary cities*: These cities exhibit moderate economic growth and have a diverse range of economic activities primarily serving local, regional (neighbouring major cities), and national markets. They often have significant agricultural sectors influenced by migration. The third group comprises *pressure-prone secondary cities*: These cities face economic and social pressures, often housing lower-middle-class residents who work in nearby major cities. Sometimes referred to as "laggard" cities, they tend to experience economic decline (Roberts and Hohmann, 2014).

Bogor is an old city established to support the economic, social, and governmental activities of Jakarta, the primate city of Indonesia. Since Jakarta was designated as the capital of the Republic of Indonesia in 1945, it has quickly grown and become the centre for many political activities and the economic prosperity of the country. All central government operations are based in Jakarta, and the city houses the central political institutions, including the highest legislative and judicial bodies, as well as the headquarters of the Indonesian National Army. In terms of economic activities, Jakarta has seen significant development in the services sector, particularly in trade and public services. Additionally, most of the headquarters of major economic and business entities operating across Indonesia are located in Jakarta.

Jakarta is a coastal city that has spatially developed in a shape resembling the letter "T", with Jakarta at the centre, connecting cities to its west, east, and south (Fig. 1). Jakarta's growth is driven primarily by its activities in services and industry, supported by enhanced accessibility through an extensive road and rail network, along with public transportation. Meanwhile, Bogor, located to the south, at the foot of Mount Salak, has positioned itself as a city focused on agriculture, history, and tourism. Between Bogor and Jakarta lies Depok, which functions as a hub for education and residential living. Unlike Bogor, which is still about 35 km away from Jakarta, the cities of Bekasi and Tangerang appear to have merged with Jakarta. As a result, Jakarta and its surrounding cities functionally form an urban region known as Jabodetabek (Jakarta-Bogor-Depok-Tangerang-Bekasi), often referred to as the Greater Jakarta Area.

The rapid growth of Jakarta and its neighbouring cities, particularly Tangerang and Bekasi, as key centres for service and industry, presents a challenge for Bogor to sustain its role as a city with historical and tourism functions. In light of these pressures and the evolving dynamics of the Greater Jakarta Area, this research focuses on the challenges faced by Bogor in maintaining its distinctive functional strengths. Can Bogor preserve its unique characteristics in the future while continuing to serve as a counterbalance to Jakarta's bustling metropolis? This analysis will be conducted through an examination of urban history, with a focus on regional functions. We will explore the development of Bogor within the context of the Greater Jakarta Area and its own city structure. This approach will help identify the factors that contribute to Bogor's sustainability and resilience, as well as those essential for understanding its functions and characteristics.

Strengthening secondary cities contributes to more equitable and sustainable urbanization, helping to reduce regional disparities and promote inclusive growth (Roberts, 2014; UN-Habitat, 2020; OECD, 2016). For developing countries, in particular, secondary cities offer a means to prevent the over-centralization of economic and political power in a single metropolitan area, promoting a more inclusive form of national development.

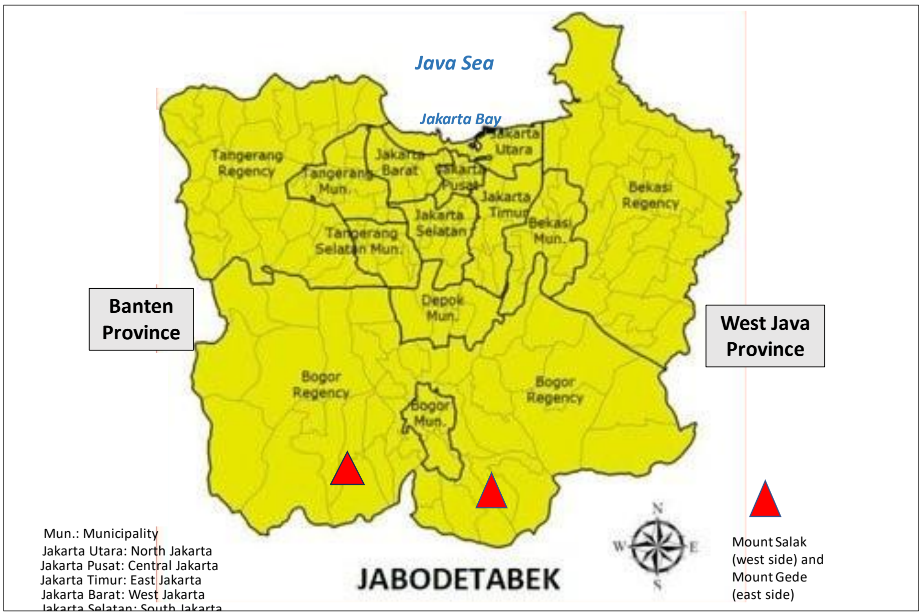

Fig. 1 – Jabodetabek (Greater Jakarta) administrative area.
Source: adapted from Pravitasari (2015).

2. STUDY METHOD

This research was conducted using the case study method across time and space, a qualitative approach in Human Geography (Baxter in Hay and Cope, 2023). A case study involves a comprehensive examination of a single unit to understand a broader class of units. In social science, this method is known as idiographic research, characterized by its depth-oriented approach and focus on specific details to understand phenomena more comprehensively. When conducting case studies across time and space, the results can be enhanced by examining multiple cases in one of two ways: first, by generating a broader basis for exploring theoretical concepts and explanations of phenomena; and second, through long-term or longitudinal case studies, which, in the case of Bogor, can provide valuable insights for a further exploration of relevant theories. Both approaches support the credibility and trustworthiness of the concepts or theories and the explanations of the case studied.

The study focuses on the concepts of territoriality and relationality in the context of Bogor as a secondary city relative to Jakarta as a primate city, with comparisons to other secondary cities in the Greater Jakarta region (Jabodetabek). According to Terlouw (2023), the concept of territoriality emphasizes the political system of government as applied to geographical characteristics, while relationality focuses on interpersonal relationships or institutional interactions within economic (social) activities, marketing, and trade or industry. Both concepts have experienced fluctuating developments in response to long-term dynamics. The discussion is divided into three stages: the establishment of Bogor up to the period before independence, the period after independence, and the development following the Reform Era. By examining the relationship between territoriality and relationality, we can better understand Bogor's position relative to Jakarta's urban dynamics and its role within the metropolitan region of Jabodetabek or Greater Jakarta.

3. STUDY AREA: BOGOR AS A SECONDARY CITY

Bogor is a secondary city with a unique position among the Greater Jakarta area. Situated at the foot of Mount Salak, Bogor benefits from higher rainfall and a cooler average temperature compared to other Jabodetabek cities. The city is also a cultural meeting point between the Sundanese and Betawi cultures. It is home to the largest agricultural university in the country and several agricultural research centres. Bogor is historically significant, featuring many important colonial Dutch and British sites, serving as a key location for Chinese migrants in the 20th century, and playing a role in the fight for national independence. Some residents choose to live in Bogor due to its 'rural romanticism,' contrasting with the more industrialized and modern cities in Jabodetabek, such as Bekasi and Tangerang. These characteristics continue to define the city. Bogor City and its surroundings host various factories, including those producing tires, agricultural machinery, medicine, and dairy products. Additionally, Bogor functions as a tourism city known for its historical significance and biodiversity, and serves as a hinterland for Jakarta, supplying food items such as tea, coffee, vegetables, and tropical fruits.

Jabodetabek is the most developed region in Indonesia, primarily due to its central location around Jakarta, the nation's capital. Jakarta serves as the hub for governance, politics, international relations, as well as the economy, trade, and information technology (Bappeda Provinsi Jakarta, 2017). As the centre for these functions, Jakarta acts as a barometer for national development. This rapid development attracts people from across Indonesia, particularly from Java. Consequently, the growth of cities in the vicinity of Jakarta, including Bogor, is closely connected to the dynamics of the capital city. This connection is further reinforced by the increasing number of transportation options linking these cities to Jakarta. Jabodetabek spans approximately 6,400 km^2, with Jakarta city itself covering around 640 km^2. The region extends about 50-60 km from Jakarta's city centre, bordering the Java Sea to the north and being surrounded by mountains to the south (Fig. 1).

4. THE HISTORY OF BOGOR

The Birth and Early Development of Bogor. In pre-colonial times, the area where Bogor would later be established was of significant military and strategic value, as well as being particularly fertile. Pakuan, the capital of the Sunda Empire (often referred to as the Pajajaran Empire), is believed to be located in what is now Bogor. The capital was the seat of Prabu Siliwangi (also known as Sri Baduga Maharaja Ratu Haji I Pakuan Pajajaran), who was crowned on June 3, 1482. This date was later adopted as the city's anniversary by the local government of the regency and city of Bogor and is still celebrated annually.

During the Dutch colonial era, Bogor's cool climate, due to its location at the foot of Mount Salak, made it a popular resort town. Its relative distance from the hustle and bustle of other major cities contributed to its appeal. The Dutch named the city "Buitenzorg" which means "without worries". Buitenzorg was located in Kampung Baroe, an area consisting of nine villages. The title for the village head of Kampung Baroe, Demang, was later changed to Regentschap Buitenzorg by the colonial authorities. The name Bogor, which in the local dialect refers to a type of tree that provides a staple food for the locals (known as *tunggulkawung* or the enau tree), was later adopted (Alwi Syahab, 2016).

The population of Bogor remained relatively stagnant during the pre-colonial era, 48,271 being the highest recorded population. After the Scipio expedition of1687 by the Dutch East Indies, followed by the Adolf Winkler expedition of1690, and the Abraham van Riebeck expeditions of1703, 1704, and 1709, sites were discovered in an old forested area. These sites and their ruins later became significant features of the newly developed region (Zakaria, 2010). During the Scipio expedition, which primarily aimed at exploration, a troop of Dutch East Indies workers (*werktroep*) under the leadership of Lieutenant Tanujiwa was tasked with clearing the forest for agriculture. This effort led to the establishment of *Kampung Baroe* (New Village). Other villages in the area were later developed under the governance of *Kampung Baroe*.

Under Governor-General Baron van Imhoff, Bogor was established as a resort town for the Dutch working in Batavia (now Jakarta), and the Bogor Palace was constructed during his tenure in 1745. During the construction of the palace, van Imhoff was granted land rights (*eigendom*) to the land around *Kampung Baroe*. Subsequent Governor-Generals had to purchase these rights (Zakaria, 2010). The design of the palace was inspired by Blenheim Palace, the residence of the Duke of Marlborough near Oxford, England (Sekretariat Negara, 2020). In 1834, the palace was severely damaged by an earthquake and was rebuilt under Governor-General Albertus Jacob Duijmayer Van Twist, with a revised design modelled after 19^{th}-century European architecture. The palace was used as a vacation home for Dutch Governor-Generals and was named the Buitenzorg Palace.

In 1817, the land around the Buitenzorg Palace, which at that time spanned approximately 47 hectares, was used to establish the Bogor Botanical Garden. The garden was managed by C.G.C. Reinwardt, the Director of Agriculture, Art, and Science. At that time, the Governor-General was Baron van Der Capellen. However, the previous British Governor-General, Thomas Stamford Raffles (1811-1816), had already created a British-style garden around the palace, which inspired the development of the Botanical Garden. At its inception, the garden featured at least 20,000 types of plants spread across 6,000 species. Initially, it served as a testing ground for agricultural plants intended for introduction to other regions of the colony.

The establishment of the Bogor Botanical Garden marked the beginning of organized natural science in Indonesia, particularly in the field of botany (1880-1905). This development led to the creation of other scientific institutions, such as the Bibliotheca Bogoriensis (1842), Herbarium Bogoriense (1844), Cibodas Botanical Garden (1860), Treub Laboratory (1884), and the Zoology Museum and Laboratory (1894). These institutions continue to operate today and were further reinforced by the founding of the Bogor Institute of Agriculture in 1963.

The Bogor Botanical Garden is the largest botanical garden in Southeast Asia and is a prominent icon of Bogor, alongside Bogor Palace. Both landmarks are situated in the central area of the city and serve as key attractions. The botanical garden has become a central part of the city's identity and remains one of its major draws. In 1903, the Dutch colonial government enacted the Law of Decentralization to address the inefficiencies of the centralized government system. Between 1903 and 1940, several municipalities (*stadsgemeenten*) and regencies (*gewesten*) were established across Indonesia by the colonial authorities. Batavia (now Jakarta) was the first *stadsgemeenten* formed in 1905, followed by others. Bogor was officially granted city status in 1920. Ir. Thomas Karsten (1884-1945) was a planner responsible for designing many of these new cities. His approach emphasized modernization and social concerns. His designs included detailed land allotments, roadway typologies, green public sanitation, and building regulations covering borders and residential housing types. Bogor was one of the cities designed by Karsten. He was conceptually opposed to traditional city planning methods that divided areas based on ethnic lines or sentiments. Instead, he favoured dividing residential areas based on socio-economic levels. In the context of spatial planning, Karsten's modernization approach represents a positivistic perspective, viewing spatial planning as an objective rather than a subjective process.

Bogor's Role in the City's Early Development. The development of a city is profoundly influenced by regional development policies. Such policies, often enshrined in laws, provide direction for development efforts in both urban and rural areas and play a crucial role in shaping the social dynamics of the affected region. Through these policies, capital flows into strategic and fundamental development projects, stimulating activity within the community. In its early days, Bogor's development was marked by a significant change in the function of Bogor Palace. Initially serving as a resort under Governor-General van Imhoff, the palace was repurposed by Daendels as the official residence of the Governor-General. As Buitenzorg (the former name of Bogor) was to be given its own administrative function separate from Batavia, an administrative centre (*algemeenesecretarie*) was constructed near the palace (Zakaria, 2010). The enhanced functionality of Buitenzorg, with its new administrative centre, botanical garden, and various departments of the colonial government, including the ministries of agriculture and education as well as laboratories and museums, underscored its growing prominence and strategic value. This importance was further solidified with the construction of a train station in 1873, connecting Buitenzorg to Batavia. These developments transformed Buitenzorg into a socially and economically thriving city.

The native Indonesians living in Buitenzorg trace their roots to the people of the Sunda Empire, also known as the Pajajaran Empire. To the north were the inhabitants of Batavia, and nearby towns such as Depok and Cibinong had a mix of Sundanese and Batavian heritage. The development of Jakarta, with its increasing interconnectedness and diversity, also attracted immigrants from various cultural backgrounds to Buitenzorg. Consequently, colonial Buitenzorg evolved into a multifunctional city, serving as an administrative centre, a resort, and a hub of research and education. As deforestation opened more land for agriculture and the population of Buitenzorg grew, markets expanded, focusing primarily on the distribution of fruits and vegetables.

After the end of Indonesia's colonial period in the 1940s, Buitenzorg was renamed Bogor. In 1941, Buitenzorg was granted autonomy and became officially independent from Batavia. According to Decree No. 11/1866 issued by the Governor-General of the Dutch colonial government, along with Decrees No. 208/1905 and No. 289/1924, Bogor covered an area of 22 km^2, comprising two sub-districts and seven villages. Following Indonesia's independence in 1945, Law No. 16/1950 granted Bogor the status of administrative city (Praja). At that time, Bogor consisted of two sub-districts and sixteen areas. By 1981, Bogor had expanded to include 22 *kelurahan* (a type of administrative division) and five sub-districts, with one representative sub-district upgraded to full sub-district status in 1992. The city continued to grow, reaching six sub-districts and 68 *kelurahan* by 2020.

During its development in the Pajajaran era and colonial times, Buitenzorg acquired the following geographical characteristics:

- As a hinterland near Batavia, it became a centre for colonial activities, particularly as a producer of fruits and vegetables.
- It served as an administrative and economic hub for the Dutch East India Company.
- It functioned as a "transit area" between Batavia and Parahiyang, with Bandung as its centre.
- Due to its verdant aspect and cool atmosphere, large forested areas, and plantations, Buitenzorg became a popular resort, attracting foreign investors to reside there.
- It was the residence for Governor-Generals.
- It developed into a centre for botanical and agricultural science, hosting the Botanical Garden, botanical and zoological museums, and various other research and educational institutions.
- These developments attracted capital, labour, transportation, technology, businesses, and social organizations, leading to Buitenzorg becoming a prominent colonial city.

- Over time, Buitenzorg became more open, with residential areas for foreign migrants developing alongside those for non-migrants.
- Throughout the colonial era, Buitenzorg experienced an increasing trend in population growth and the expansion of residential areas, effectively enlarging the city.

Bogor: Post-Independence. After the end of colonial rule, Buitenzorg was renamed Bogor in 1950. Many historical landmarks remain icons of the city, including the landscapes of Pakuan Pajajaran, Buitenzorg Palace, and the Botanical Garden. Other significant sites, such as fishing ponds, mosques, churches, garrisons, courthouses, prisons, markets, stations, town halls, and the Resident's office, are also part of the city's heritage. Following the 1950s, Bogor began to develop its own local identity. However, in the mid-1960s, Indonesia experienced a political crisis with the upheaval of the Orde Lama (Old Order) under Sukarno, which adversely affected Bogor's development. The impact of the colonial legacy, as well as the brief Japanese occupation (1942-1945), remain significant. Despite these challenges, the city's development continued to place the Botanical Garden at its centre, symbolizing the city's identity.

Bogor's development is closely linked to Jakarta, due to its role as a satellite secondary city. As Jakarta developed at a much faster pace, Bogor was formally included in the Greater Jakarta development master plan for 1965-1985. During this period, Jakarta's Governor, Ali Sadikin, envisioned Jakarta as Indonesia's primary city. Under his direction, the provincial government of Jakarta sought partnerships with neighbouring provincial governments, particularly regarding land use for suburban residential areas.

This master plan marked the first instance where the development of a region and its cities was directly overseen by the national Indonesian government, with contributions from Dutch and American planners. It was subsequently named the Jakarta Metropolitan Regional Plan. The primary objective of this plan was to establish new development areas by distributing industry, residential areas, and public facilities to regions adjacent to Jakarta, namely Bogor, Tangerang, and Bekasi. This planning effort was systematic and scientific, incorporating one of the first uses of spatial analysis. Dutch planners conducted urban and regional planning courses in Bogor, as well as in Tangerang and Bekasi, in 1973. The detailed aspects of the plan were developed thereafter (Hanggoro, 2018).

A core idea of the plan was to manage Jakarta's rapid growth, which was surpassing its capacity. Adjacent cities were identified as secondary cities and were developed to alleviate the pressure on Jakarta. These cities include Tangerang to the west, Bekasi to the east, and Depok and Bogor to the south. The goal of developing these new central regions was to make them attractive enough to discourage people from settling in Jakarta, thereby extending Jakarta's capacity to these neighbouring cities.

To the south of Jakarta, new residential areas were developed in Depok, Cibinong, and Citeureup. In Depok, housing for middle-class employees of state-owned enterprises was constructed, along with the main campus of Universitas Indonesia. A highway connecting Jakarta to Bogor, passing through Cibinong and Citeureup, was also built. This road aimed to accelerate development in Cibinong and Citeureup, which were known for their fruit trade and industry. Bogor was designated as a centre for agricultural research and education, thanks to its existing institutions, such as the Institut Pertanian Bogor (IPB) or Bogor Agricultural Institute. Additionally, Bogor was developed to serve as a hinterland for distributing agricultural products to Jakarta. A double railway system was constructed to enhance accessibility between Jakarta and its secondary cities.

In 1977, Ali Sadikin stepped down as Jakarta's governor. His legacy includes numerous development projects in Jakarta and its surrounding areas, collectively known as Jabodetabek (Greater Jakarta), of which Bogor is a part. Ali Sadikin emphasized the borders between cities as markers for their potential development. During his tenure, he also improved public facilities and promoted local artists and culture. However, some of his decisions, such as the legalization of prostitution and gambling, were controversial. These developments were crucial for Jakarta's evolution into a modern metropolis (Hanggoro, 2018).

By 1977, Jakarta was home to nearly 6 million people. Covering an area of 587.62 km^2, the city had a population density of 8,334 people per km^2. At that time, this density was significantly higher than any other major city in Indonesia. Jakarta also accounted for at least 50% of the nation's financial transactions. By 1977, there were 329 projects with foreign investment (Penanaman Modal Asing, PMA) and 687 projects with domestic investment (Penanaman Modal Dalam Negeri, PMDN) in Jakarta. The total investment value in Jakarta represented over 50% of all PMA and PMDN in the country, despite the city having only 4.2% of the national population (Hanggoro, 2018).

After Jakarta's Governor, the city evolved into a metropolitan structure that attracted investors and migrants from both within and outside Java Island. It became a central hub for various activities in Indonesia and set a benchmark for the development of other cities. Due to extensive development, most of its open spaces were transformed into built-up areas, leading to high urbanization. Migrants from across Indonesia, particularly from neighbouring cities like Bogor, sought employment in Jakarta, and many relocated with their families. By 1990, Jakarta's population reached 8.19 million, growing at a rate of 4%, nearly double the national average. Within just five years, the population surged to 9.1 million (BPS, 2015).

The development of the Greater Jakarta Area, particularly the southern region from Jakarta to Bogor during the 1980s and 1990s, focused on rapidly expanding built-up areas. This growth was supported by the construction of transportation routes, including highways, toll roads, and double railways. The restoration of the Jakarta-Bogor main road via Cibinong and the development of a parallel toll road enhanced accessibility to and from Bogor (*Badan Penelitian Pengembangan Perhubungan*, 2015). Residential development in areas near these new roads was also accelerated. Consequently, migration from Jakarta to surrounding cities, including Bogor, increased. This trend was further bolstered in the 1990s by the rise of banking companies that offered loans for property purchases (Cahyadi, 2009). In the late 1990s, Jakarta experienced a population decline of 2.41%. This trend continued into 2000, with the city's population growth slowing to just 0.14%, one of its lowest growth rates on record (BPS Provinsi DKI Jakarta, 2016) (Fig. 2).

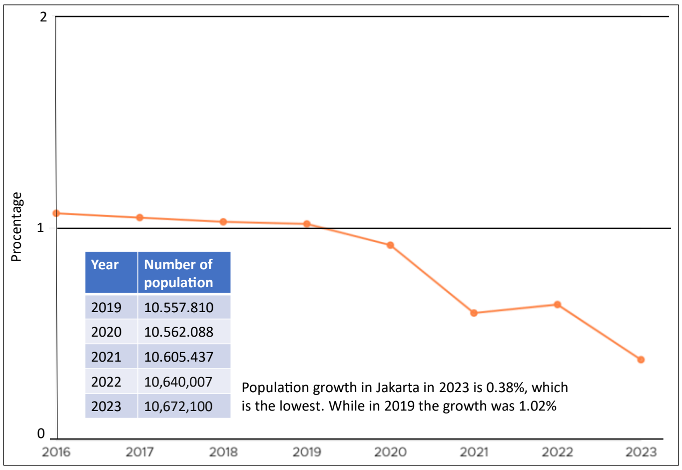

Fig. 2 – Population Growth in DKI Jakarta Province 2016–2023.
Source: BPS DKI Jakarta, 2024.

Development after the Reformasi Era. In 1998, Indonesia underwent significant political and structural changes, marking the beginning of the Reformasi Era. This period saw a massive decentralization effort, with the implementation of direct elections for regional governments, including provinces, cities, and districts. Jakarta, which operates as a provincial government, does not elect the heads of its five cities and one district; instead, these officials are appointed by the governor (Nurlambang, 2013). Decentralization has altered the dynamics and mechanisms of development. Regional governments, being more attuned to the needs of their constituents, often have a closer understanding of local issues compared to the national government. However, the autonomy of regional authorities can also lead to divergence from national development goals. Regional leaders may sometimes fail to recognize that their decisions impact not only their own region but neighbouring regions as well. Development is inherently complex, and interactions between regions are inevitable, regardless of administrative boundaries. This underscores the necessity for a robust national development strategy (Nurlambang, 2013).

Decentralization has also led to increased disparity and further exploitation of natural resources, resulting in environmental degradation, such as deforestation (Bappenas, 2012). Development focused solely on economic and political objectives is not sustainable. The degradation and disparity are particularly evident in critical resources, such as water in northern Java, especially within the Greater Jakarta Area (Oktaviani, 2019). The frequency of natural disasters, including floods and landslides, has increased, especially in densely populated areas that are also prone to earthquakes (BNPB, 2010). Bogor, situated at the foot of Mount Salak and Mount Gede – both active volcanoes – does not face significant water scarcity or high flooding risks due to its relatively steep terrain.

To mitigate risks, the central government has implemented a zoning plan. This plan covers a region larger than Jabodetabek (Jakarta, Bogor, Tangerang, and Bekasi), extending to include Depok and Cianjur, thereby creating the Jabodetabekjur (Jakarta, Bogor, Depok, Tangerang, Bekasi, and Cianjur) metropolitan area. Governed under Presidential Decree No. 54/2008, the zoning plan aims to reduce the environmental impact of development. However, its effectiveness is limited in curbing existing market mechanisms that have transformed land use within Jabodetabekjur (Figs. 3a and b).

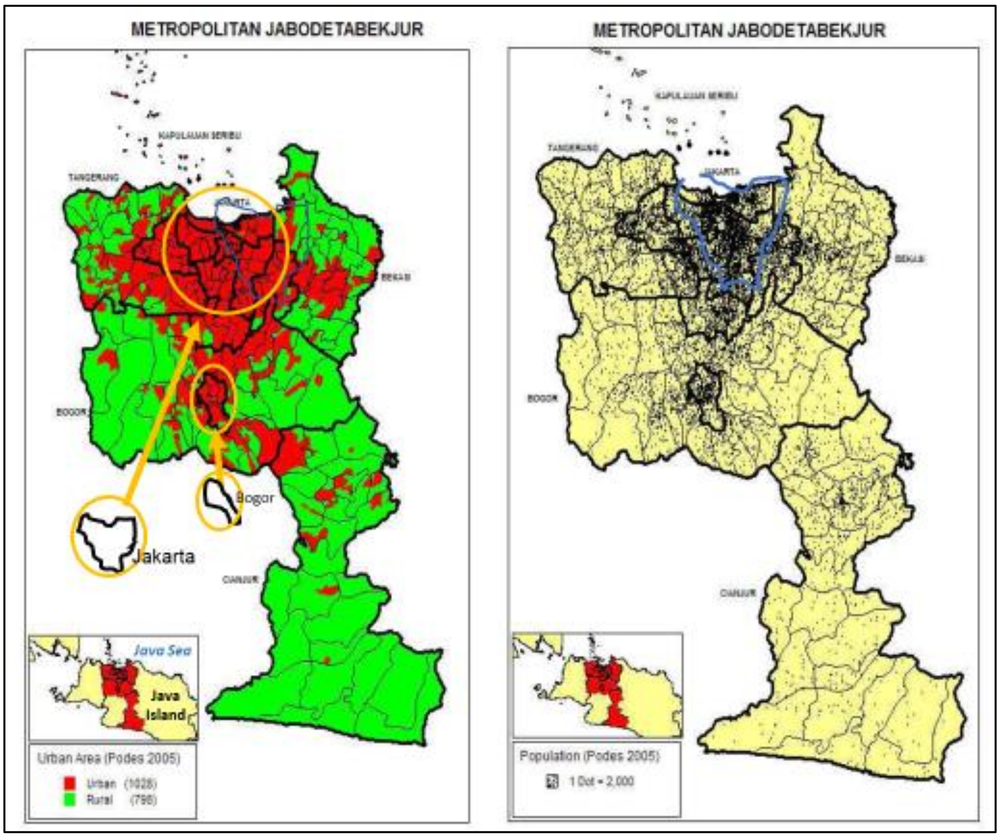

Fig. 3a – Build up area and 3b. population distributionin Metropolitan Jabodetabekjur (Jakarta-Bogor-Depok-Tangerang- Bekasi and Cianjur) or Greater Jakartain 2005.
Source: Nurlambang, 2013.

Table 1

Basic Issues and Spatial Development Policies in Metropolitan Jabodetabekjur (Greater Jakarta).

Metropolitan Concept	Issue/problem	Policy	Spatial arrangement
Jabotabek (1975/6)	Un-equal role and function of primary city and secondary cities (Jakarta highly dominate)	Growing faster its secondary cities	***Bundled deconcentration*** • Hierarchical function among cities • Hierarchical urban/spatial structure
Jabodetabek – Bopunjur (1999)	*Over-spill* (as a consequence of over-capacity) and *urban sprawl*	Managing a metropolitan area	***Metropolitan*** • One big urban system and entity • Spatial structure as one greater urban system
Jabodetabekjur (2008)	• Basic resources scarcity (mainly water resources) and lack of infrastructure services (as well as public services). • Local government conflicts due to decentralization system	Controlling and environmental development mainstreaming	***Zoning system*** • Controlling spatial utilization • environmental development mainstreaming
Jabodetabekjur (2020)	The high growth of build-up areas and spread across all parts of the region. Commercial buildings, offices and residential/apartment buildings along with TOD (Transit Oriented Development) increased quite rapidly. Public transportation networks are built to overcome congestion, such as the LRT and MRT.	Greater Jakarta as a Metropolitan to become a highly economic-business competitive and sustainable Global City.	Strengthening as a Metroplitan with Jakarta as a Core City and the surrounding area is an area with an urban nature. Congestion remains a problem.

Source: Nurlambang, 2013 and Presidential Degree no. 60/2020 on Jabodetabek Spatial Planning

Decentralization was assessed by the government in its 10th year, revealing that many development efforts were focused solely on economic and political goals, or benefited only certain groups (Nurlambang, 2018 and 2019). Law No. 32/2004 on Regional Autonomy, which served as the legal foundation for decentralization and district and city governance, was revised by Law No. 23/2014 on Regional Governments. This revision revoked several decisions previously granted to regional authorities, transferring authority back to the central government or provincial governments, particularly concerning the management of vital and strategic resources. Additionally, development funds are now managed and supervised by the central government, resulting in a more unified and systematic approach to national development at the regional level (Wasistiona and Petrus, 2017).

The effects of decentralization and regional autonomy are also evident in Jakarta and its neighbouring cities and districts. As decentralization progressed, Jakarta's population increased, and new residential areas developed around the city, accompanied by an expansion in transportation options. Consequently, many people migrated to the newly developed suburbs on the city's outskirts. This trend indicates that development is increasingly influenced by market forces rather than central government directives (Nurlambang, 2013). As a result, Jakarta has become Indonesia's most expensive city to live in. The cost of living in Jakarta reached 7.5 million rupiah (US$ 778) per month in 2012, a trend that has persisted in subsequent years. In contrast, the cost of living in Bogor, located just south of Jakarta, was 4.47 million rupiah (US$ 463) per month forthe same year. Depok, also south of Jakarta, had a monthly living cost of 6.33 million rupiah (US$ 656), Bekasi, to the east,- 5.77 million rupiah (US$ 598), and Tangerang to the west had a monthly living cost of 4.69 million rupiah (US$ 486) (Biaya.net, 2014).

Living in Bogor and other cities adjacent to Jakarta has become a rational choice. With increasingly varied access to Jakarta, this option has become much more attractive. Alternatives to the Jagorawi (Jakarta-Bogor-Ciawi) toll road include the double rail commuter trains, which were renovated in the early 1990s. The Jakarta-Bogor commuter line saw an average annual growth rate of 2.3%, with 17.3 million active users in 2019. Duringthe same year, the Jakarta-Bekasi line was used by 14.8 million passengers, and the Jakarta-Tangerang line by 15.02 million (Dwiwanto, 2020). This data suggests that Bogor is likely the most popular option for workers commuting to Jakarta.

In addition to having significantly lower living costs compared to Jakarta, public facilities in Bogor are relatively well-developed, including its public education and healthcare systems. These factors make Bogor a more attractive option compared to living in Jakarta. The city's appeal is further enhanced by its cool climate, abundant rainfall, resort-town image, tourist attractions (such as natural sites and culinary centres), and historical significance.

The relocation of Jakarta residents to Bogor was anticipated in the planning of the Jabodetabek region. The implementation of this plan included the construction of residential areas catering to lower, middle, and upper-class residents in Bogor and other adjacent cities. Accessibility infrastructure was also planned, including the Jagorawi toll road (connecting Jakarta to Bogor) and the renovation of commuter train services, both of which were key factors in accelerating Bogor's development.

Prasetyo, Raldi, and Tarsoen (2016) analysed and explained urban sprawl using the Shannon Entropy method. In 1989, urban sprawl in Bodetabek (the region surrounding Jakarta, excluding Jakarta itself) was 5.93%. This figure grew to 11.99% in 2000 and further increased to 25.73% by 2014. This sprawl encompasses residential areas, commercial zones, and industrial zones, including both environmental and social facilities. A ribbon development pattern dominates this sprawl, following major roads and railways from Bekasi in the north to Bogor in the south.

In addition to the growing number of residential areas in Bogor and along the Jagorawi toll road, many manufacturing sites and warehouse areas have been established. Most of these sites are concentrated in Cibinong and Citeureup, between Jakarta and Bogor. The development of these industrial zoneshas also spurred the creation of new residential areas. The expansion of built-up areas along the Jagorawi toll road has further reinforced the ribbon development pattern in the region. By 2005, 58% of Bogor had become built-up areas. These areas are predominantly suburban, located in North Bogor, East Bogor, and Tanah Sereal in Central Bogor, accounting for 70% of the total built-up areas. The remaining built-up areas include commercial buildings such as malls, factory outlets, hotels, and restaurants, as well as social infrastructure like hospitals, mosques, universities, and schools (Azzam, 2015). These developments reflect a ribbon pattern extending north and east of Bogor (Fig. 4).

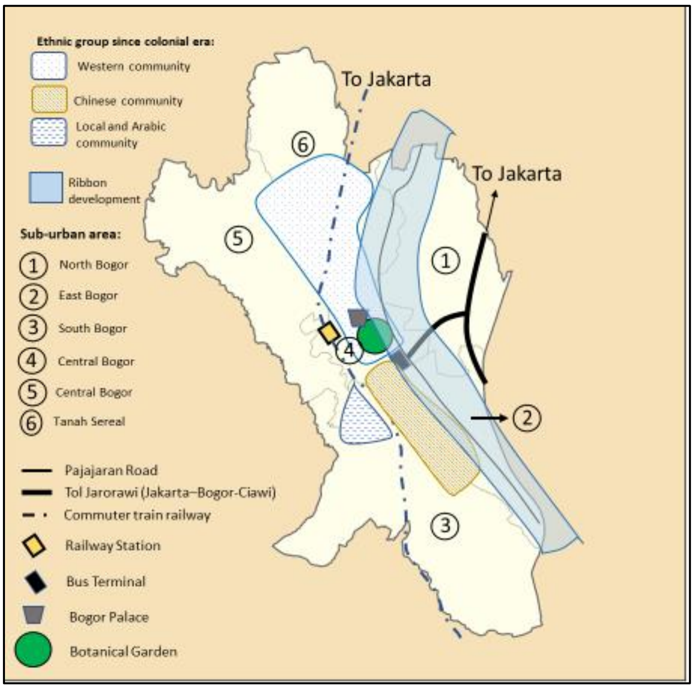

Fig. 4 – Bogor City.
Source: adapted from Bappeda Kota Bogor, 2011.

By 2015, 39% of Bogor's land was used for residential areas. Residential development was most active in the 1980s and was primarily conducted by private companies in western, northern, and eastern Bogor. In 1990, a state-owned company, the General National Housing Company (Perusahaan Umum Perumahan Nasional/Perum Perumnas), played a significant role in transforming a large portion of land in East Bogor into housing for middle and middle-lower income residents. The housing developed in Bogor was predominantly land-based, as apartments were not popular at the time. Bogor's increased accessibility contributed to this housing boom, particularly with the renovation of the highway connecting East Bogor – where many new residential areas were built–to Jakarta. A bus terminal also provided a route connecting Bogor and Jakarta via this highway, while residents in North Bogor could easily access Jakarta via commuter trains.

Given these characteristics and developments, it is reasonable to describe Bogor as Jakarta's secondary or "suburban" city. Most migrants who settled in Bogor commute to Jakarta for work, making Bogor also a dormitory town. Despite being located in West Java, separate from Jakarta's province, the functional connections between the two cities are significant for regional development. Jakarta serves as a livelihood centre for many Bogor residents, while Bogor provides tourism and recreational opportunities for Jakarta's inhabitants.

The Influence of Jakarta

Due to the enactment of the Jakarta Metropolitan Regional Plan in the 1970s, Bogor has effectively been within Jakarta's sphere of influence. Over the 50 years since that plan was first implemented, Jakarta has remained one of the fastest-growing cities in the country. This growth has significantly impacted its adjacent regions, such as Tangerang and Bekasi to the west and east of Jakarta. Jakarta's expansion has encroached upon the spatial planning of these cities, making it challenging to view them as separate entities.

Meanwhile, the built-up areas extending from Jakarta's development have reached approximately 35 kilometres from the southern edge of the city, which has helped Bogor remain relatively shielded from direct physical influence. Since becoming the nation's capital, Jakarta has continued to attract growth and development. By 2019, Jakarta's population had reached 10.5 million people (BPS DKI Jakarta, 2020). In contrast, the populations of adjacent cities average only around 1–3 million (BPS West Java, 2020; BPS Banten, 2020). Jakarta's influence as a primate city extends beyond its neighbouring secondary cities such as Bogor, Depok, Tangerang, and Bekasi, impacting the country as a whole, particularly in relational terms.

Since 2014 and 2015, infrastructure development has been a national priority, resulting in numerous residential projects along highways extending north, east, and south of Bogor. These highways are crucial for accessing the Jagorawi toll road, which, initially opened with two lanes, expanded to four lanes by 2020. Data from 2017 indicates that the road is used by an average of 180,000 to 190,000 vehicles annually (BPJT, 2018). The Jagorawi toll road has the second-largest vehicle volume in Indonesia. In 2019, the central government announced plans to move Indonesia's capital from Jakarta and Java to East Kalimantan (Bappenas, 2019). This relocation is planned to take place over five years and was formalized by the enactment of Law No. 2 of 2022, which establishes the new state capital in East Kalimantan, replacing the previous legislation concerning Jakarta. Consequently, a special law regarding Jakarta will be issued in early 2024 to address its new status.

The shift of the capital is expected to diminish Jakarta's political and economic centrality and reduce the pressure to develop and utilize land in the city. Functions such as government, national economic and political roles will be transferred to the new capital. This change will impact Jakarta's subordinate functions and essential services like water, food, housing, transportation, and other social services. The relocation may also affect Jakarta's adjacent satellite cities, including Bogor, potentially decreasing the city's role in supporting Jakarta and slowing its economic and population growth.

The Staying Power of Bogor's Functionality

The influence of major cities like Jakarta on secondary cities such as Bogor remains dominant. The lifestyle of Bogor's residents, particularly migrants who work in Jakarta, has disrupted traditional ways of life. This shift is evident in the growing number of modern shopping centres and cafes within the city and in its outskirts, such as Sentul, located in the northeastern part of Bogor. Many of these establishments are franchises from Jakarta. Traditional shopping at local stores on Suryakencana Street or at markets near the Botanical Garden is declining.

According to the spatial development plans for 2011–2031, Bogor has been designated a National Activity Centre (Bappeda, 2011). This designation is part of the Greater Jakarta (Jabodetabekjur) National Strategic Plan. Bogor is expected to accommodate 1.5 million people as a supporting city to Jakarta. Consequently, Bogor is in a precarious position, with ongoing shifts threatening its traditional and historical values. While Bogor's city planning falls under the regional development framework of West Java province, its proximity to Jakarta – approximately 35 km – is significantly more impactful than that of Bandung, the capital of West Java, which is about 122 km away via Cianjur.

Government decentralization in Indonesia has provided Bogor with the opportunity to develop and strengthen its position as a secondary city. Its history as an imperial centre, a popular resort town during colonial times, and its rapid modernization in recent history have all influenced the city's ability to manage itself. Preserving and even strengthening its identity is crucial for its survival. Therefore, incorporating the concept of resilience is essential in efforts to maintain the city.

The development of Bogor is characterized by a tension between its historical sites, such as the Botanical Garden and Bogor Palace, local communities including Sundanese, Chinese, and Arab settlements, and the influence of Jakarta's regional development. These tensions are expected to shift further as Jakarta is set to lose its status as the capital and a new capital to be established in East Kalimantan in 2024 or 2025. This transition will likely reduce the influence of Jakarta on Bogor. It is important to anticipate this change to ensure the preservation of Bogor's identity and function.

Bogor serves as the hinterland for Jakarta, as well as Tangerang and Bekasi. The agricultural sector has grown yearly by approximately 5% over the past three years, since 2020, with about 62% of the total agricultural business dedicated to food crops and livestock (BPS Kota Bogor, 2023).

Secondary cities will play a crucial role as catalysts and secondary hubs in facilitating the localized production, transportation, transformation, and transfer of goods, people, trade, information, and services across sub-national, metropolitan, national, regional, and global city systems. These cities are expected to exhibit industry agglomeration and clusters, well-developed localized supply chains and networks, a diversified economic and employment base, and a broad housing mix.

However, not all secondary cities are alike. There are growing disparities in economic, physical, and social development between different city systems. This has led to widening gaps in income, poverty, and employment levels, particularly between primary and secondary cities. Many secondary cities struggle to raise capital and attract the investment necessary to build infrastructure, foster productive enterprises, and develop vibrant communities. These challenges hinder the creation of dynamic economies, improved livelihoods, and job opportunities.

Addressing how to enhance connectivity, efficiency, investment generation, and employment in secondary cities is critical for creating more dynamic local economies, ensuring greater equity and development opportunities, and stimulating trade and competition between city systems. This entails understanding the relational dynamics within a large territory, such as Greater Jakarta and its surrounding cities. From a geographical perspective, the term "relational" often refers to functional properties that describe territorial characteristics. Although Bogor City is part of West Java Province and distinct from Jakarta Province, this does not diminish its relational importance within the broader regional context.

5. CONCLUSIONS

What values does Bogor need to become resilient and sustainable? A balanced system in terms of its functions can preserve the role of each region or city. Maintaining a balanced system of its functions is essential for preserving the role of each region or city. This balance is particularly crucial for Bogor, given its place within the Greater Jakarta development plan (Jabodetabekjur). The city's primary strengths lie in its tourism sector, with its historical significance, and its agricultural sector, particularly food crops and animal husbandry. In fact, Bogor functions as a hinterland for the cities of Jakarta, Bekasi, and Tangerang.

Aligned with the 11th Sustainable Development Goal (SDG) of making cities inclusive, safe, resilient, and sustainable (Bappenas, 2017; Hoffmann, 2015), Bogor has the potential to meet these objectives. With its current resources, the city is projected to accommodate up to 1.5 million people by 2025 (Bappeda Bogor, 2011). This indicates a remaining capacity of 400,000 as of 2020. Given the normal population growth trend of 1.6% per year, the city's capacity should remain sufficient through 2025. However, this growth requires careful attention from the city, its residents, and its government.

There must be a collective awareness among Bogor's citizens of their city's historic roots, which date back to the Pajajaran Empire and its administration under Dutch and British colonial rule. Two notable icons from this period of history are the Botanical Garden and Bogor Palace. Additionally, Bogor's identity as an academic hub, with its universities and agricultural research centres, as well as its status as a resort town due to its location at the foot of Mount Salak, cool temperatures, and substantial rainfall, all contribute to its unique character. These identities shape the values of Bogor's residents and are essential for maintaining the city's distinctiveness. Preserving these values not only enhances Bogor's attractiveness, but also supports its capacity and sustainability.

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THE IMPACT OF SMART TRANSPORTATION ON THE IMPROVEMENT TRANSPORTATION SERVICES THROUGH THE YASSIR APPLICATION. A CASE STUDY OF THE NEW CITY OF ALI MENJELI – CONSTANTINE (ALGERIA)

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Key-words: Smart transportation, Yassir application, transportation services, transportation efficiency, transportation technology.

Abstract. This study examines the impact of smart transportation, specifically the Yassir ride-hailing application, on improving transportation services in the new city of Ali Menjeli in Constantine, Algeria. Using a questionnaire distributed to 151 residents, the research analyses the extent of smart transportation use and transportation service quality in relation to service improvement. Statistical analysis, including regression models, has revealed a significant positive effect of both smart transportation use and service quality on improving overall transportation services. The Yassir application was found to contribute to increased efficiency, reduced waiting times, improved safety, and decreased traffic congestion. The study highlights the growing acceptance and benefits of smart transportation technologies in urban mobility, particularly in newly developed cities. The findings suggest that integrating such applications can lead to enhanced transportation experiences and urban quality of life.

1. INTRODUCTION & LITERATURE REVIEW

Urban transportation systems are crucial for the economic and social functioning of cities (Muhasen, Shahin, 2019). However, traditional transportation systems often struggle with issues like traffic congestion, pollution, and inefficiency. In recent years, smart transportation has emerged as a promising solution to addressing these challenges (Figueiredo, 2021). Smart transportation refers to the use of advanced technologies, such as artificial intelligence, Internet of Things (IoT), and big data analytics to improve the efficiency, safety, and sustainability of transportation systems (Zhuhadar *et al*, 2017).

The concept of smart transportation is closely linked to the broader idea of smart cities. Müller-Eie and Kosmidis (2023) define smart cities as urban areas that leverage technological solutions to enhance the management and efficiency of the urban environment. Smart transportation is considered one of the six key components of smart cities, alongside smart governance, economy, environment, living, and people (Müller-Eie, Kosmidis, 2023).

Smart transportation systems offer numerous potential benefits; they can help reduce traffic congestion through real-time traffic management and route optimization (Gharehbaghi, 2019). These

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systems can also improve safety by providing real-time alerts and implementing advanced driver assistance systems (Mäkinen, 2021). Furthermore, smart transportation can contribute to environmental sustainability by promoting the use of public transport and reducing emissions through a more efficient traffic flow (Zhuhadar *et al.*, 2017).

One of the key enablers of smart transportation is the proliferation of ride-hailing applications. These apps, such as Uber, Lyft, and local variants like Yassir in Algeria, have transformed urban mobility by providing on-demand transportation services (Tirachini, 2020). Ride-hailing apps can potentially reduce private car ownership, increase vehicle occupancy rates, and provide last-mile connectivity to public transport systems (Jin, 2018).

However, the implementation and impact of smart transportation systems can vary significantly depending on the local context. While much research has focused on developed countries and major metropolitan areas, there is a need for more studies examining the adoption and effects of smart transportation in developing countries and newly developed urban areas (Neves, 2020).

This study aims to address this gap by examining the impact of smart transportation, specifically the Yassir ride-hailing application, on transportation services in the new city of Ali Menjeli in Constantine, Algeria. Ali Menjeli is a planned city developed as part of Algeria's urban expansion strategy, providing an interesting case study of smart transportation adoption in a newly developed urban area.

The research objectives of this study are:

1. To assess the extent of smart transportation use through the Yassir application in Ali Menjeli.
2. To evaluate the quality of the transportation services provided by the Yassir application.
3. To analyse the impact of smart transportation on improving overall transportation services in the city.

Based on these objectives, the following hypotheses have been put forward:

1. H1: The extent of smart transportation use has a significant positive effect on the improvement of transportation services in Ali Menjeli.
2. H2: Transportation service quality has a significant positive effect on the improvement of transportation services in Ali Menjeli.
3. H3: The use of smart transportation and transportation service quality collectively have a significant positive effect on improving transportation services in Ali Menjeli.

By examining these hypotheses, this study aims to contribute to the understanding of smart transportation impacts on newly developed urban areas in developing countries, potentially informing policy and planning decisions for similar contexts.

The concept of intelligent transportation: Smart transportation is one of the most important tools for organizing traffic in the city. It works to improve the efficiency of transportation and traffic networks while using modern technologies and communications in the fields of electronic visual, as well as audio communication and computer programs to analyse and process data in traffic management centres. The aim is to solve traffic problems in the city (Abdelwahad, 2018, p. 11).

The definition of intelligent transportation: The use of computer, electronic, communication, and control technologies to address many of the challenges facing surface transportation, such as improving traffic safety, productivity, and public mobility in the face of worsening congestion, persistent safety hazards, and tight transportation agency budgets (Al Mashhadani, 2019, p. 2260).

The definition of Intelligent Transportation Systems (ITS): Intelligent transportation systems are the natural evolution of the infrastructure of the transportation sector through its modernization in order to keep up with information. This is very important because as the demand for transportation increases, intelligent transportation systems help to absorb a large capacity with higher efficiency, without relying entirely on the establishment of new transportation facilities. Furthermore, intelligent transportation systems apply modern technologies in the field of monitoring, information collection, control, communication and computer programs so as to maximize the absorption capacity of the road network and other means of transportation. Additionally, the basics of intelligent transportation systems are divided into three sections, which are as follows (Al Mashhadani, 2019, p. 2261).

Table 1

Basics of Intelligent Transportation Systems

Data collection methods	**Data processing technology**	**Command and control and information transfer**
Devices that collect the appropriate data, such as traffic control and development on highways, city roads, and surveillance cameras in parking lots and public transportation.	The software and hardware that process data and respond to changes in these systems.	The technologies involved in bringing the results of data processing to reality and coordinating them with public transportation.

The purpose of the transportation sector is no longer simply to move people and goods from one place to another, but to achieve economic, social, and environmental sustainability. Given the complexity of transportation systems, governments and cities must manage conflicting demands to provide safe, efficient, reliable, and environmentally friendly transportation systems.

Technology has been playing a major role in shaping transportation systems since the dawn of time. This is evident when analysing the evolution of transportation systems from a historical perspective, as technological innovations have introduced structural and profound changes to transportation systems around the world; the following are some of the major inventions and innovations that have shaped the history of transportation (United Nations, 2021).

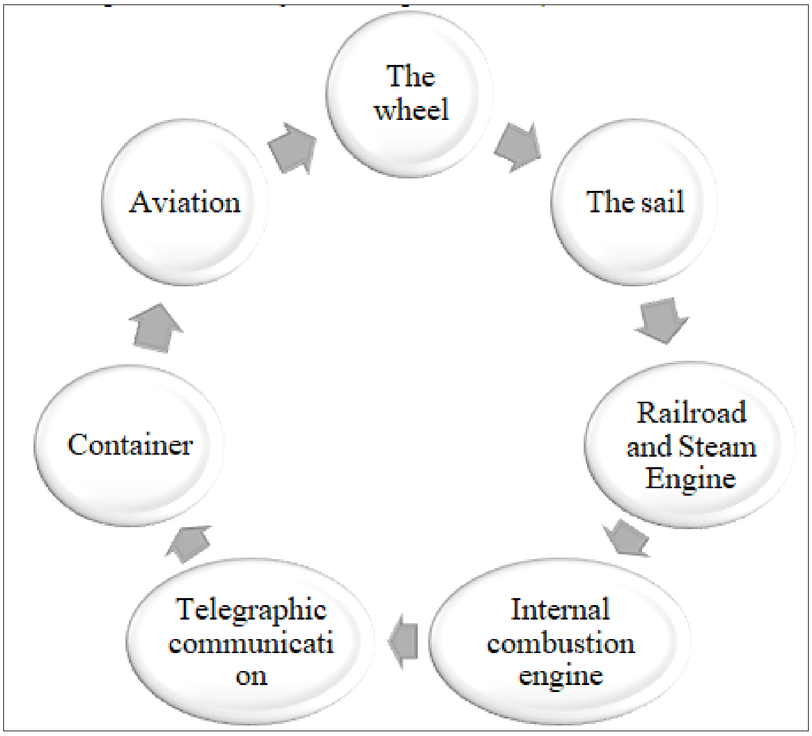

Fig. 1 – Some of the major inventions and innovations that have marked the history of transportation.

Given the critical importance of ITS, several countries have been working to implement them. In the table below are some of the applications being pursued by various countries (Boulkouas, 2014, p. 161):

Table 2

Applications of Intelligent Transportation Systems for Public Transportation Development

Intelligent Transportation Systems Applications	Definition
Automatic roads	A means of achieving the goal of the most technically challenging long-range intelligent system, a complete road and vehicle system that is operationally complete and automates the driving process. On the other hand, the introduction of an automated road system improves traffic safety by minimizing human error as the main cause of accidents, and improves road efficiency by automatically controlling vehicles and regulating their speed and the distance between them.
Surveillance cameras in front of traffic lights	It has already been proven to reduce accidents at the intersections where they are set up.
Geographic Information System (GIS) utilization and information management technology	It is a mechanism used by direct drivers to find out the location of bottlenecks, speed up their resolution, and notify drivers through 100 billboards and digital screens on the road.
Smart information organizer	It balances traffic volume between regular ways and highways, removes critical traffic bottlenecks, and provides traffic information.
Global Positioning System (GPS)	This technology is considered the most widely used, and this system represents a navigation system consisting of a network of satellites installed in specific orbits in outer space. In 1980, the US government allowed it to become available for civilian use. It is a system that can, for example, pinpoint the location of the vehicle in the event of an accident. This system can detect everything that is both moving and static, as the satellite detects and sends the result of the detection to the receiver (the information analysis centres).

The importance of technology emerges as one of the vital components that work to develop the transportation sector, and is manifested in the manufacture and renewal of modes and spare parts, the continuation of basic and complementary equipment for transportation and transportation, the use of electronic computers and satellites, the introduction of self-control systems, and the increase in capacity, and control leading to more savings and cost reduction. These activities are as follow. (Lakhdar, 2019, p. 709).

The role of ITS in improving transportation:

– Smart technologies improve transportation by enhancing safety, efficiency, and user experience, as well as by reducing congestion and pollution. This contributes to boosting the quality of life and well-being of society as well as the following:
– Improving safety and security: Smart technologies, such as sensors, help improve the monitoring and early detection of safety issues, such as traffic accidents, helping to prevent them, enhancing user safety, and protecting lives.
– Improving efficiency and productivity: Smart technologies, such as automated control systems and artificial intelligence, improve enhance efficiency, reduce costs, increase productivity, and save energy.
– Improving user experience: Smart technologies such as connected car apps, and audio and entertainment systems enhance the user experience in transportation, providing a higher level of comfort and well-being.
– Improving urban mobility: Smart technologies help improve urban mobility and reduce road congestion, such as navigation applications and intelligent transportation systems in buses, trains, and subways.
– Reducing pollution: Smart technologies help improve vehicle performance and fuel efficiency, reducing pollution from tailpipe emissions.

2. METHODOLOGY

2.1. Study area

According to the European Commission, smart cities are “cities that use technological solutions to improve the management and efficiency of the urban environment”, but also “go beyond the use of information and communication technologies to use resources and reduce emissions”. A smart city has six components: Smart Government, Smart Economy, Smart Environment, Smart Living, Smart Mobility, and Smart People. From a strategic perspective, an approach that covers all six dimensions can be seen as an overarching strategy and goal for a smart city. Smart cities have been characterized by tools such as smart technology and IOT, open data, public-private collaboration, competition, and user engagement, claiming that automatically collected data and competition between cities can lead to societal benefits, convenience, and better resource allocation. Key stakeholders in a smart city are the city government, the planners, politicians, policymakers, technology and consulting firms, knowledge organizations, and the residents (Müller-Eie, Kosmidis, 2023, p. 2).

- **The New City of Ali Menjeli – Constantine**:

Creation: Named after Ali Menjeli, a mujahid of the Algerian Liberation Revolution, the new city is an urban pole in the wilaya, according to Algeria’s policy on new cities within the general strategy of the National Urbanization Plan implemented by Law No. 87/03 of January 27, 1987 on urbanization. This project was confirmed by the master plan for the urbanization of Constantine by Decree No. 83/98 of 25/02/1998 and inaugurated by Presidential Decree No. 217/2000 of 5/8/2000 (Ministry of Housing, Urbanization and City, 2024).

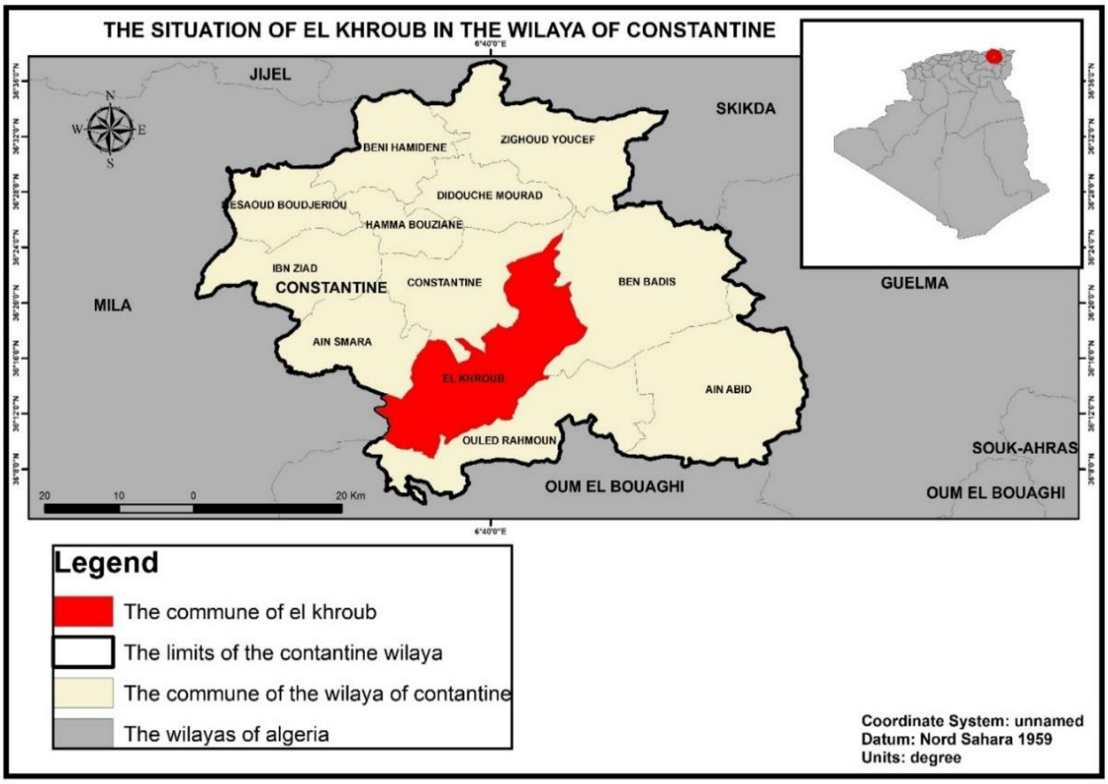

Fig. 2 – Situation of Khroub – the new city of Ali Menjeli – Constantine Governorate.

Location and borders: This new city – Ali Menjeli – is located on the surface of Ain El Bey, which can be found about 13 km south of Constantine, near the city centre and the municipalities of El Kharroub and Ain El Samara. The total area of the city is estimated at 2341 hectares, consisting of 20 neighbourhood units with a 120-hectare multi-activity zone: 1500 hectares, where the western expansion is 384 hectares, the southern expansion is 287 hectares, and the University City is 170 hectares (Fadel, 2021, p. 409). According to Prof. Salma Mesbah 2006, Human and City Laboratory, Montouri University, Constantine, it extends north to the borders of the east-west highway, northeast to the borders of Mohamed Boudiaf Airport, west to the foothills of the Ain al-Bay plateau, south to the Aifour foothills, and south to the Aish train. On the other hand, it can be found in state and municipal documents and associations that extend to include the Aish train and Salih Darraji in the south (Rachidi, Fallahi, 2020, p. 148). The map provides the following overview:

This new urban settlement is organized into a dense, multifunctional main centre (District Units 6 and 7), around which are 20 adjacent neighbourhood units, numbered from 1 to 20, whose formation and urbanization process has gone through three major moments. The first, from 1985 to 1999, saw the city's area increase from 0.03 to 0.51 km. The urban expansion during this period took the form of Neighbourhood Unit 6 and a small part of the business park to the north of the town. During the second stage, from 1999 to 2010, the built-up area grew steadily, reaching 7.12 km with an extremely high annual growth rate of 118.53%. The local authorities launched several large-scale projects and facilities, which led to the revitalization of several neighbouring units that make up the new town. Thirdly, the built-up area accelerated sharply from 2010 to 2019, reaching more than 11.84 square kilometres. In addition, urbanization expanded on the southern and western extensions, which were merged (Benhenni, Alkama, 2024, p. 210).

- **The Yassir application:** Yassir is a private Algerian startup that is a "platform or app" that connects customers with drivers online. Created in 2017 by "**Noureddine Tibi**" in Palo Alto, California, it offers VTC services via a mobile app available on iOS and Android. Various services can be accessed, including instant rides, reservations, airport packages, multi-stop rides, and hourly driver services. It is available in six countries around the world (Algeria, Côte d'Ivoire, France, Morocco, Senegal, and Tunisia) and has more than 5 million users. The company covers about 80% of the on-demand transportation market in the Maghreb. The startup's core values are:
  - We are committed to delivering unparalleled quality products, setting the standard for excellence.
  - Our team's boundless ambition drives us to innovate, grow, and reach new heights.
  - Open communication and transparency are the cornerstone of our relationships, fostering trust and cooperation.

The app's logo looks like this:

Fig. 3 – Yassir app logo.

To use Yassir services, you need to create a personal account on the mobile app, after downloading it from the App Store, and then simply enter your name, surname, email address, and mobile number. Once your account is created, you can order your first ride; here are the steps to make the order:

- Enter your delivery address.
- Choose the vehicle class you want along the corresponding fare.
- Choose between requesting an instant ride and a pre-booking.
- Click "Request Now" to confirm the ride. You will then receive a notification with the driver's details (driver's name, phone number, car type, and license plate). You can track the driver's location in real time on the app. You have 5 minutes after confirmation to cancel the ride at no charge (Yassir, 2024).

2.2. Data and tools

2.2.1. Study tools

The study was conducted through the questionnaire, one of the primary data collection tools, to determine the impact of smart transportation as represented by a simple application in improving transportation services in the new city – Ali Menjeli – in the state of Constantine, divided into three axes, namely:

- **The first axis**: contains statements related to the demographic characteristics of the sample members.
- **The second axis**: contains statements related to the independent variable (smart transportation).
- **The third axis**: contains statements related to the dependent variable (improving transportation services).
- **The fourth axis**: measures the effect of the independent variable on the dependent variable (the effect of smart transportation on improving transportation services).

Initially, the five-point "**Likert**" scale was used to measure the attitudes of the sample members towards the questions of the questionnaire, and the gradation in the scale used was taken into account as follows:

Table 3

Gradient in the scale used

Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
5	4	3	2	1

To determine the length of the pentagonal Likert scale (lower and upper limits), the range (5-1=4) was calculated, meaning the difference between the highest value and the lowest value of the pentagonal Likert scale, as well as to obtain the correct category length, which is the range divided by the number of Likert categories (3), which is (4/3 = 1.33). Then, this value was added to the lowest value in the scale, which is the correct one, to determine the upper limit of this category. Consequently, the category length becomes as follows:

[1–2.33] The degree of agreement is weak.
[2.34–3.67] The degree of agreement is moderate.
[3.67–5] The degree of agreement is high.

2.2.2 The population and study sample

The population of the current study is the population in the new city of Ali Menjali – Constantine, where a simple random sample of 151 residents was taken, and the questionnaire was distributed electronically, collecting data from January to April 2024.

2.2.3. Statistical treatment

To test the hypotheses of the study, a set of statistical analysis tools was used, in addition to the statistical program SPSS (version 25) in order to perform the necessary statistical analyses:

- **Percentages**: To present the characteristics of the demographic variables.
- **Arithmetic mean**: To know the average attitudes of the respondents regarding the questionnaire paragraphs, and to determine the degree of their acceptance.
- **Standard Deviation**: To know the amount of dispersion in the opinions of the respondents concerning each paragraph of the questionnaire.
- **Pearson's correlation coefficient (r)**: To measure the degree of relationship between the dependent variable and the independent variable.
- **Coefficient of determination (R2)**: To know the proportion by which the independent variable affects the dependent variable.
- **Simple linear regression model**: To test the relationship between the independent and dependent variables.

2.2.4. Stability of the study

This refers to the cohesion of the stability coefficient, meaning that is does not contradict itself, providing the same results if it is reapplied to the same sample after a short period of time. In this case, we point out that the closer the values of Cronbach's alpha are to one, the higher the stability, and vice versa. The following table shows Cronbach's alpha values for the axes of the study.

Table 4

Cronbach's alpha test

Axes	Number of paragraphs	Cronbach's alpha axes
Independent Variable (Smart Transportation)	08	0.611
Dependent variable (improving transportation services)	08	0.845
The effect of the independent variable on the dependent one (impact of smart transportation on improving transportation services)	08	0.867
The questionnaire as a whole	24	0.901

From the table above, we can see that Cronbach's alpha coefficients are all acceptable, as they are greater than 0.60, which is a high level of stability and, therefore, the reliability of the questionnaire being evaluated.

Analysing the results of the study

a. Descriptive analysis of demographic data:

Table 5

Distribution of the study sample according to demographic characteristics

Sample characteristics		Repeats	The ratio
Gender	Male	52	34.4%
	Female	99	65.6%
Age	18 to 25 years old	48	31.79%
	25 to 60 years old	103	68.21%
Educational level	Intermediate	01	0.7%
	Secondary	02	1.3%

Table 5 (continued)

	Higher education	**148**	**98.00%**
Professional status	Student	50	33.1%
	Employee	72	47.7%
	Daily worker	1	0.7%
	Unemployed	26	17.2%
	Retired	2	1.3%
Yassir Application usage time	Morning	34	22.5%
	Midday	32	21.2%
	Evening	75	49.5%
	Night	10	6.6%

It is clear from the results of the descriptive analysis of the study sample, according to its demographic characteristics, that most of the sample members are university degree holders, as many as 98.00%, which helps in understanding the phrases of the questionnaire and thus giving credibility to the results of the field study. The sample members are young, as the percentage of those aged between (25–60 years) reached 68.21%, while those aged between (18–25) years made up 31%. Through the descriptive analysis of the sample members, we note that men amounted to 34.4%, while the percentage of women reached 65.6%. As for the professional status of the customer, we note that the majority of users of the Yassir application are employees (47.7%), and then students (33.1%). The remaining percentage, rather low, indicates that the users of the Yassir application are the educated group that uses technology in their personal lives.

Three statements were used to facilitate this study descriptively:

– "The extent of use of smart transportation".
– "The quality of transportation service".
– "The impact of smart transportation on improving transportation services".

b. Descriptive analysis of the phrase "the extent of use of smart transportation"

Table 6

Descriptive statistics for the statement "The extent of use of smart transportation"

No.	**Ferries**	**Sample size**	**Arithmetic mean**	**Standard deviation**	**Direction**
01	Citizen uses smart transit for safe access	151	4.08	1.017	High
02	A citizen prefers to use smart transit over urban transit.	151	3.93	1.083	High
03	The individual uses smart transit to speed up his/her arrival	151	4.56	0.617	High
04	The customer prefers Yassir over other apps	151	4.04	0.993	High
05	Customers find it very easy to use the app	151	4.32	0.788	high
06	Being able to use technology enhances the use of smart transportation	151	3.77	0.918	high
07	Internet connectivity is a prerequisite for using smart transit.	151	4.73	0.577	high
08	Lack of transportation causes the need to use smart transportation	151	4.66	0.701	high
Extent of use of smart transportation			4.2632	0.44327	high

We note from Table 6 that the arithmetic mean of the statements regarding the extent of using smart transportation is 4.26 with a standard deviation of 0.44327 (there is no dispersion in the responses of the sample members). Since the arithmetic mean of the statements regarding the extent of using smart transportation is significantly different from the degree of neutrality (hypothetical mean = 3) and exceeds it by 1.26, the attitude of the sample members is high, and they agree with the statements regarding the extent of using smart transportation.

c. Descriptive statistics for the phrase "quality of transportation service":

Table 7

Descriptive statistics for the phrases "Quality of transportation service"

No.	Ferries	Sample size	Arithmetic mean	Standard deviation	Direction
01	Transportation meets all the requirements of the citizens in the new city	151	3.76	1.269	High
02	The customer uses public transportation for all his movements	151	3.71	1.214	High
03	Transportation covers the entire territory of the new city	151	3.59	1.333	High
04	Transportation provides all the comfort requirements for commuters	151	3.46	1.399	High
05	The new city of Ali Menjeli is characterized by traffic congestion	151	4.44	0.763	high
06	The customer finds it difficult to access transportation	151	4.02	1.042	high
07	Mobility reaches its destination in the shortest time	151	3.68	1.283	high
08	Transportation offers many services at a lower cost	151	3.81	1.145	high
Quality of transportation service			3.8088	0.82813	high

We note from Table 7 that the arithmetic mean of the transportation service quality statements is 3.8088 with a standard deviation of 0.82813 (there is no dispersion in the responses of the sample members), and since the arithmetic mean of the cognitive dimension of Algerian tourists towards the Turkish tourist destination is significantly different from the degree of neutrality (hypothetical mean=3) and exceeds it by 3.8, the attitude of the sample members is high, and they agree with the quality of the transportation service.

d. Descriptive statistics for the phrases "the impact of smart transportation on improving transportation services"

Table 8

Descriptive statistics for the statements "The impact of smart transportation on improving transportation services"

No.	Ferries	Sample size	Arithmetic mean	Standard deviation	Direction
01	Smart transportation contributes to safer transportation	151	4.12	1.026	High
02	Smart transportation contributes to mobility at a lower cost	151	3.66	1.376	High
03		151	4.53	0.671	High
04	Smart transportation can increase accessibility	151	4.52	0.720	High
05	Smart transportation provides services more quickly	151	3.70	1.200	high
06	The new city of Ali Menjeli is characterized by the availability of the Internet to facilitate the use of smart transportation	151	3.52	1.500	high
07	The use of smart transportation reduces air pollution	151	3.85	1.325	high
08	Smart transportation services offer solutions to eliminate traffic congestion	151	3.59	1.348	high
The impact of smart transportation on improving transportation services			3.8088	0.82813	high

We can see from Table 8 that the arithmetic mean of the statements regarding the impact of smart transportation on improving transportation services is 3.9346 with a standard deviation of 0.84973 (there is no dispersion in the responses of the sample members). Since the arithmetic mean of the statements regarding the impact of smart transportation on improving transportation services differs from the degree of neutrality (hypothetical mean = 3) and exceeds it by 0.93, the attitude of the sample members is high, and they agree with the statements regarding the impact of smart transportation on improving transportation services.

3. RESULTS AND DISCUSSIONS

Based on the presentation of the field results obtained following this study, and on the appropriate statistical tests for each of the study's hypotheses, we will try to answer the latter, as well as interpret and analyse these results.

3.1. Testing the first sub-hypothesis

There is a statistically significant effect at the level of significance (a≤0.05) regarding the extent of **using smart transportation** to **improve transportation services**, and Table 9 showcases the results of the simple linear regression test for the first sub-hypothesis:

Table 9

Summary of the results of the regression and variance analysis to test the first sub-hypothesis

<table>
<tr><td rowspan="4">Independent variable
Using smart transportation</td><td colspan="7">Dependent variable
Improving transportation services.</td></tr>
<tr><td>Correlation coefficient
r</td><td>Coefficient of determination $\mathbf{R^2}$</td><td>Adjusted coefficient of determination</td><td colspan="2">Independent variable coefficient
B</td><td colspan="2">Fixed part
a</td></tr>
<tr><td rowspan="2">0.431</td><td rowspan="2">0.186</td><td rowspan="2">0.180</td><td>Independent value</td><td>Significance level</td><td>Constant value</td><td>Significance level</td></tr>
<tr><td>0.826</td><td>0.000</td><td>0.413</td><td>0.498</td></tr>
<tr><td colspan="4" rowspan="4">Estimated equation:
Y_1= 0.413 + 0.826 X
Where:
X: Using smart transportation.
Y_1: Improve transportation services.</td><td colspan="4">Analysis of Variance ANOVA</td></tr>
<tr><td colspan="2">**F**
test for the model</td><td colspan="2">**t**
test for the model</td></tr>
<tr><td>F coefficient value</td><td>Significance level</td><td>Coefficient t</td><td>Significance level</td></tr>
<tr><td>33.987</td><td>0.000</td><td>5,830</td><td>0.000</td></tr>
</table>

- **Evaluating the use of smart transportation to statistically improve transportation services:**

a. Partial Significance (Significance of Parameters): Partial significance is expressed through the significance of the estimated parameters:

- **Constant (a):** It is the significance that is determined at a value of 0.05 for all other variables, and in this case the coefficient of the constant is 130.4, at a significant value of 0.498, which is greater than 0.05, which indicates that the constant is not significant and is not statistically significant.
- **Parameter of the independent variable (use of smart transportation):** It is the significance that relates to the effect of using smart transportation on the dependent variable (improving transportation services). Based on the model, we find that the slope (B) reached a value of 0.826, at a significant value of 0.000, which is below the significance level of 0.05, which indicates that the slope is significant and statistically significant. That is, the variable of using smart transportation has a significant and statistically significant effect on improving transportation services.

b. Overall Significance (Model Significance): Based on the data in Table 9, we find that the reliability of the model depends on the level of significance of the F coefficient. If the value of the significance level is under 0.05, the model is considered significant. Based on our data, the significance level of the F coefficient is 0.000, which is significantly below 0.05, which means that the model is highly significant.

The computed exact Fisher's value is the value of the F coefficient given by the analysis of variance, which is estimated from the F data: 33.987. Therefore, the calculated Fisher's value is 33.987, which is a significant value and indicates that the model is highly significant.

Based on the data, the model is highly significant where the significance level of the F coefficient is 0.000, and the calculated Fisher's value is 33.98, it can be said that the model takes a linear form, where there is a statistically significant effect of using smart transportation to improve transportation services.

c. Explanatory power (goodness of fit): The explanatory power of the model is tested using:

– **Correlation coefficient**: The correlation coefficient (r) ranges between -1 and 1, with values close to 1 or -1 indicating a strong correlation, and values close to 0 indicating no correlation. In the model, the correlation coefficient between using smart transportation and improving transportation services is 0.431, which is statistically significant at the 0.05 significance level. Since the model is statistically significant at the 0.05 significance level, this means that there is a correlation between the use of smart transportation and its impact on improving transportation services statistically significant.

– **Coefficient of Determination** R^2: 0.186, meaning that the independent variable of using smart transportation contributes to explaining the variations of the dependent variable to improve transportation services by 18.6%, which is a rather weak percentage. It means that there are other factors (81.4%) that contribute to explaining the identified variations of transportation service improvement, indicating that the model could be more accurate if other independent variables were included.

Based on the analysis of the results in Table 9, the hypothesis that "there is a statistically significant effect at the level of significance (a≤0.05) regarding the extent of using smart transportation to improve transportation services" was accepted for the following reasons:

– **The significance level for Fisher's F is 0.000**: Since the significance level is under 0.05, it indicates that the model is highly significant and that there is a significant linear relationship between the independent and dependent variables.

– **Correlation coefficient r = 0.431**: indicates that there is a moderate direct correlation between the use of smart transportation and the improvement of transportation services.

– **Coefficient of determination R^2 = 0.186**: Indicates that the use of smart transportation contributes to explaining about 18.6% of the variations in improving transportation services, and although this percentage is not very high, it does prove that there is an actual effect.

– **Coefficient value of t = 5.830**: It shows that the effect of the independent variable (use of smart transportation) is significant in relation to the dependent variable (improving transportation services).

3.2. Testing the second sub-hypothesis

There is a statistically significant effect at the level of significance (a≤0.05) regarding **transportation service quality** on **improving transportation services**, and Table 7 showcases the results of the simple linear regression test for the second sub-hypothesis:

Table 10

A summary of the results of regression analysis and the analysis of variance for testing the second sub-hypothesis

Independent variable **Transportation service quality**	Dependent variable **Improving transportation services**.						
	Correlation coefficient **r**	Coefficient of determination $\mathbf{R^2}$	Adjusted coefficient of determination	Independent variable coefficient **B**		Fixed part **a**	
				Independent value	Significance level	Constant value	Significance level
	0.698	0.487	0.484	0.716	0.000	1.207	0.000
Estimated equation: **Y_1= 1.207+ 0.716 X** Where: X: transportation service quality. Y_1: Improve transportation services.				Analysis of Variance ANOVA			
				F test for the model		t test for the model	
				F coefficient value	Significance level	Coefficient t	Significance level
				141.43	0.000	11.893	0.000

- **Evaluating transportation service quality for statistically improving transportation services:**
  a. **Partial Significance (Significance of Parameters):** Partial significance is expressed through the significance of the estimated parameters:
     – **Constant (a):** It is the significance that is determined at a value of 0.05 for all other variables, and in this case the coefficient of the constant was 1.207, at a significance value of 0.000, which is under 0.05, which indicates that the constant is significant and statistically significant.
     – **Independent Variable Parameter (Transportation Service Quality)**: It is the magnitude that relates to the effect of transportation service quality on the dependent variable (improving transportation services). Based on the model, we find that the slope (B) reached a value of 0.716, at a significant value of 0.000, which is below the significance level of 0.05, which indicates that the slope is significant and statistically significant. That is, transportation service quality has a significant and significant effect on improving transportation services.
  b. **Overall Significance (Model Significance):** Based on the data in Table 10, we find that the significance of the model depends on the level of significance of the F coefficient, as the calculated Fisher's value is estimated based on the data F: 141.432, which is a significant value and indicates that the model is highly significant, so it can be said that the model takes a linear form, where there is a statistically significant effect of transportation service quality on improving transportation services.
  c. **Explanatory power (goodness of fit):** The explanatory power of the model is tested using:
     – **Correlation coefficient**: The correlation coefficient (r) ranges between –1 and 1, with values close to 1 or -1 indicating a strong correlation, and values close to 0 indicating no correlation. In the model, the correlation coefficient between transportation service quality and transportation service improvement is 0.698, which is statistically significant at the 0.05 level of significance. Since the model is statistically significant at the 0.05 level of significance, this means that there is a statistically significant correlation between transportation service quality and transportation service improvement.
     – **Coefficient of determination $\mathbf{R^2}$:** 0.487, meaning that the independent variable of transportation service quality contributes to explaining the variations of the dependent variable to improve transportation services, with a percentage of 48.7%, which is a normal

percentage. It means that there are other factors (51.3%) that contribute to explaining the variations in improving transportation services.

Based on the analysis of the results in Table 10, the hypothesis “There is a statistically significant effect at the level of significance (a≤0.05) regarding transportation service and the improvement of transportation services” that is accepted for the following reasons:

– **The significance level of Fisher’s coefficient F is 0.000**: Since the significance level is under 0.05, it indicates that the model is highly significant and that there is a significant linear relationship between the independent and dependent variables.
– **Correlation coefficient r = 0.698**: It is a high value indicating that there is a strong correlation between transportation service quality and the impact of smart transportation on improving transportation services. The correlation is also statistically significant at the 0.05 significance level, which reinforces the acceptance of the hypothesis.
– **The coefficient of determination R^2 = 0.487**: Indicates that transportation service quality explains about 48.7% of the variations in transportation service improvement. This percentage reflects the good explanatory power of the model and supports the studied hypothesis.
– **Coefficient value of t = 11.893**: Indicates that the effect of the independent variable on the dependent variable is significant.

3.3. Testing the main hypothesis

There is a statistically significant effect at the level of significance (a ≤ 0.05) regarding the extent of **using smart transportation** and **transportation service quality** to **improve transportation services**, and Table 11 showcases the results of the multiple regression tests for the third sub-hypothesis:

– The independent variables: (using smart transportation), (transportation service quality).
– The dependent variable: (improving transportation services).

Table 11

Summary of the results of the regression and variance analysis to test the main hypothesis

<table>
<tr><td rowspan="5">Independent variable
Using smart transportation and transportation service quality</td><td colspan="7">Dependent variable
Improving transportation services.</td></tr>
<tr><td>Correlation coefficient r</td><td>Coefficient of determination R^2</td><td>Adjusted coefficient of determination</td><td colspan="2">Independent variable coefficient B</td><td colspan="2">Fixed part a</td></tr>
<tr><td rowspan="3">0.709</td><td rowspan="3">0.502</td><td rowspan="3">0.496</td><td>Independent value</td><td>Significance level</td><td>Constant value</td><td>Significance level</td></tr>
<tr><td>0.268</td><td>0.034</td><td rowspan="2">0.316</td><td rowspan="2">0.508</td></tr>
<tr><td>0.650</td><td>0.000</td></tr>
<tr><td colspan="4" rowspan="4">Estimated equation:
$$Y_1 = 0.316 + 0.268 X_1 + 0.650 X_2$$
Where:
X_1: using smart transportation.
X_2: transportation service quality.
Y_1: Improve transportation services.</td><td colspan="4">Analysis of ANOVA Variance</td></tr>
<tr><td colspan="2">F test for the model</td><td colspan="2">t test for the model</td></tr>
<tr><td>F coefficient value</td><td>Significance level</td><td>Coefficient t</td><td>Significance level</td></tr>
<tr><td>74.710</td><td>0.000</td><td>5.830</td><td>0.000</td></tr>
</table>

- **Evaluating the "use of smart transportation" and the "transportation service quality" in statistically determining "transportation service improvement":**
  a. **Partial Significance (Significance of Parameters):** Partial significance is expressed through the significance of the estimated parameters:
    – **Constant (a):** It is the significance that is determined at a value of 0.05 for all other variables, and in this case the coefficient of the constant is 0.316, at a significant value of 0.508, which is greater than 0.05, which indicates that the constant is not significant and is not statistically significant.
    – **The parameter of the independent variables (use of smart transportation, quality of transportation service)**: It is the significance that relates to the effect of these independent variables on the dependent variable (improving transportation services). Based on the model, we find that the slope (B1) at the first independent variable (use of smart transportation) amounted to 0.268, at a significant value of 0.034, which is below the significance level of 0.05, which indicates that the slope is significant and statistically significant. We alsowe also find that the slope (B2) at the second independent variable (quality of transportation service) amounted to 0. This indicates that the slope is significant and statistically significant, which means that the use of smart transportation and the quality of transportation services have a significant impact on improving transportation services.
  b. **Overall Significance (Model Significance):** Based on the data in Table 11, we find that the significance of the model depends on the significance level of Fisher's F. This test is used to establish whether the multiple regression model as a whole is statistically significant. In this case, we find that Fisher's F value is estimated at F. 74.710, at a significance level of 0.000, which is a good value and indicates that the test results and the model as a whole provide a statistically significant explanation for the variance in the dependent variable (improving transportation services) based on the independent variables (use of smart transportation and transportation service quality).
  c. **Explanatory power (goodness of fit)**: The explanatory power of the model is tested using:
    – **Correlation coefficient:** The correlation coefficient between transportation service quality and transportation service improvement is 0.709, which is statistically significant at the 0.05 level of significance. Since the model is statistically significant at the 0.05 level of significance, this means that there is a statistically significant correlation between the use of smart transportation and transportation service quality and transportation service improvement.
    – **Coefficient of determination R^2**: 0.502 meaning that the independent variables contribute to explaining the variations of the dependent variable, with a percentage of 50.2%, a rather high percentage. This means that there are other factors (49.8%) that contribute to explaining the variations in determining the improvement of transportation services.

Based on the analysis of the results of Table 8, the hypothesis that "there is a statistically significant effect at the level of significance ($a \leq 0.05$) regarding the extent of **using smart transportation** and **transportation service quality** to **improve transportation services**" is accepted for the following reasons:

– **The significance level of Fisher's coefficient F is 0.000**: Since the significance level is under 0.05, it indicates that the model is highly significant and that there is a significant relationship between the independent and dependent variables.
– **Correlation coefficient r = 0.709**: It is a high value, indicating that there is a strong correlation between the independent variables and the dependent variable. The correlation is also

statistically significant at the 0.05 significance level, which reinforces the acceptance of the hypothesis.

– **Coefficient of determination $R^2 = 0.502$**: It indicates that transportation service quality explains about 50.2% of the variations in transportation service improvement, this percentage reflects the good explanatory power of the model and reinforces the studied hypothesis.
– **Coefficient value of t = 5.830**: It indicates that the effect of the independent variable on the dependent variable is significant.

4. CONCLUSIONS

Through this study, we have tried to identify the impact of intelligent transportation on the improvement of transport services through the Yassir application in the new city of Ali Menjeli-Constantine. A questionnaire was used to collect data from the users of the application, which were then analysed using SPSS V.25 in order to obtain a set of theoretical and statistical results. This was based on a statistical analysis and the testing of the hypotheses of the study as mentioned above.

The results showed that the Yassir application significantly contributes to improving transportation efficiency, as users can book trips quickly and easily, which reduces waiting time, thus achieving user satisfaction. This confirms the existence of general user satisfaction with the services of Yassir, especially in terms of accuracy and reliability. Yassir has helped reduce traffic congestion by improving the distribution of trips and encouraging the use of shared transportation.

The results confirmed that the use of smart technology increases the safety of transportation services by accurately tracking and locating vehicles. It also reduces costs, as smart transportation applications can reduce operations and maintenance costs by optimizing schedules and cutting down on idle time.

Smart applications work in conjunction with other transportation systems, such as trains and buses, to improve overall mobility in cities. The Yassir app saw a significant increase in the number of users during the study period, indicating a high level of community acceptance of the technology. The time taken by users to reach their destinations was significantly reduced using the app, contributing to increased productivity and an improved quality of life.

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DESIGN TRENDS FOR CHILDREN'S PLAYGROUNDS IN THE URBAN ENVIRONMENT. CASE STUDY: THE CITY OF BISTRIȚA, ROMANIA

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Key-words: design, playgrounds, urban environment, Bistrița, a model for child-friendly play spaces.

Abstract. This work showcases the latest trends in the design and arrangement of children's playgrounds in rapidly growing urban areas. The author analyses the potential capacity of playgrounds to enhance children's physical and mental development, encourage their capacity to improve children's physical and psychological growth and foster intensive learning about the world through play. The paper contains examples of using non-standard components and innovative structures and materials in playgrounds in Romania. The analysis considers the need to apply state-of-the-art technologies, and a creative approach balanced with compliance, safety rules and construction standards to build playgrounds which would be interesting and attractive for children and useful for their all-around development. The example of Bistrița compares the design for the historic districts of the city and its peripheral and districts and mentions specific requirements for designing playgrounds outlined in corresponding codes and regulations. This paper also describes the cooperation framework between project customers, designers, and neighbourhood residents (the end users of playgrounds), as in the case of Bistrița. Another task is to analyse the accessibility of a playground for people with mobility disabilities. It explores the process of selecting suitable sites, of communicating with the target audience (the residents), and the typical challenges to be addressed by planners. The research period ranges from July 2023 to March 2024.

1. INTRODUCTION

Nowadays, given the fast urban development and, in particular, the vast construction of multi-storey residential areas, the organization of safe and comfortable living environments for children and teenagers is a topical issue as, from one point of view, life in big cities gives children many development opportunities, while from another, it restricts freedom of movement and the access to the natural environment.

The classic definition of sustainable development refers to intergenerational responsibility. Meanwhile, paradoxically, children make up a social category often neglected and marginalised, while urban planning is rarely dedicated to them. We are responsible for ensuring a sustainable future and a good present for the next generations, so they become tomorrow's healthy and educated adults.

The words "play" and "children" are inseparable, and children's right to play is rightly recognised as one of the fundamental rights by the United Nations Convention on the Rights of the Child (UNCRC, 2013; Murnaghan, 2019; Morgenthaler *et al.*, 2023). According to Article 31 of the UNCRC, "Children have the right to relax and play, and to join in a wide range of cultural, artistic and other recreational activities" (UNCRC, 2013).

For children, unplanned urbanisation "means unhealthy and unsafe environments, limited options for walking and playing, and limited connectivity" (UNICEF, 2018). Playgrounds should be based on spatial planning and quality factors, including children's needs and preferences.

Compared to the older generation, modern children and adolescents tend to have fewer possibilities for playing outdoors (Shackell et al., 2018) as access to public playgrounds located between

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apartments buildings is being restricted due to numerous factors: the rise in the number of cars and the use of yards as parking spaces (Jansson Merit, 2010); a limited access to courtyards for safety; a lack of public spaces as part of the construction of new residential quarters; social factors such as parents' safety considerations when they prefer to leave children at home or at private commercial organizations under constant control, etc.

However, the presence of suitable public playgrounds in urban building estates is extremely important for proper children's development.

According to UNICEF, one of the characteristics of a child-friendly city is for children to be able to meet friends and have places to play and enjoy themselves (UNICEF, 2018).

Properly designed and equipped children's playgrounds in urban neighbourhoods secure the necessary conditions to spend a healthy amount of time outdoors, benefit from physical growth, ensure children's development and perform leisure activities with their peers.

The research of urban space to plan a landscaping project reviews the latest trends in children's playground design and the creation of a model for child-friendly play space (city recreation) in urban environments.

2. METHODOLOGY

In terms of procedure, there were two main directions:

a. The bibliography reviews the speciality in which the trends and design principles used in the setting up of a playground are analysed.
b. Observations are conducted on the ground, where the principles of design and planning of the identified space are established.

a. Designing a playground requires following certain architectural principles to help create fun, accessible play areas for children. Landscape designers know that design principles and the architectural playground equipment are two key elements when creating a playground.

As with any building, architectural design plays a significant role in creating a playground. Eight main principles of playground architecture affect every aspect of a playground. These principles ensure that play areas are accessible for all children.

When designing a playground, it's essential to provide space for various types of play so children can choose their favourite kind. Some of the most common types of play include the following: active play, creative play, and social play.

Modern playground components use sturdy, safe materials to ensure children have a play space that will withstand the elements and last for years with proper maintenance. Common types of equipment surfaces include metal, plastic, wood and rubber.

The best design will allow for adaptive and inclusive play that shifts with children's interests and abilities.

Imagine the types of activities that may go on there: physical games, creative games, social games, games that engage the senses and areas for those children who may wish to play in peace.

b. Principles used for the designing and planning of space:

Functionality: the space must be designed in such a way that it meets the needs of its users. Each area must have a clear destination and allow for specific activities to be carried out effectively.

Ergonomics: the space must be comfortable and accessible to all users. This includes the proper dimensions of furniture, accessibility for people with disabilities and a smooth flow.

Aesthetics: the design must be visually pleasing and reflect the desired style. The choice of colours, materials and textures plays a crucial role in creating a harmonious atmosphere.

Safety: ensuring a safe environment is essential. This implies being compliant with construction rules, preventing fire risks and ensuring good ventilation and lighting.

3. RESULTS AND DISCUSSIONS

The research results are divided into three segments: principles of playground design (urban recreation), trends in playground design and a model of urban space transformation.

The typology of playgrounds is influenced by their location in the urban space, their surface area, the complexity of their facilities and the degree of realization, the connection with other public functional infrastructures, and the transposition of design principles.

Principles of playground design

Playing is a need for children - it is essential for their dynamic growth, physical, mental, and emotional development, and their ability to communicate and socialize.

Playing activities establish favourable conditions for intellectual development, for visual, verbal, and logical thinking.

During play, a child complies with the rules, gets acquainted with the behaviour and relationships of adults, and garners communication and self-awareness experience.

Consequently, a game triggers feelings and emotions, encourages the volitional regulation of behaviour, and forms competitive motivation. Playing on public playgrounds can be viewed as a reflection of society, where children are encouraged to overcome fears and take risks to cope with difficulties in real life (Sheina, Sokolova, 2016).

Fig. 1 – The delimitation of the urban space where the current research is applied. A 3D rendering of urban space and its localization at the county level.
Source: Alexandru Marius Tătar, created usinghttps://3d- mapper.com/_MAP, https://app.datawrapper.de/edit.

The research materials devoted to the study of modern design trends in children's playscapes highlight the main design principles that provide the realization of the entertainment and teaching potential of open playgrounds (Design Guidelines, 2016):

– A participatory approach involving the design process of public interest groups (psychologists, educators, architects, designers, parents, etc., both specialists and end users of playgrounds).
– Safety precautions.
– Accessibility provisions for all social groups.
– Having a design for the widest possible target audience – for all ages and abilities.
– Taking into consideration the environmental characteristics of a chosen area.
– Satisfying a child's play needs, providing landscape diversity and multi-purpose elements, ensuring a variety of play scenarios.
– Having a selection of universal playing elements and modules.
– Providing opportunities for research, experimentation and learning through play.
– Appealing to children's senses.
– Providing opportunities for the identification of risks, controlling and diversifying potentially dangerous situations, and ensuring a reasonable exposure according to one's abilities.
– Designing it for year-round use and seasonal versatility.
– Accounting for the needs of accompanying parents.

Types of playgrounds identified in urban areas:
– Outdoor playgrounds;
– Park-type playgrounds without tartan flooring;
– Neighbourhood playgrounds between apartment buildings with tartan flooring.
Examples of the realization principles mentioned above:

Fig. 2 – Park-type playground.

Park-type playground located in the promenade area of inter-war Bistrița, flanked by the defensive structure of the medieval period near the city centre, the space complies with the following conditions provides accessibility for all social groups, is designed for the widest possible target audience – for all ages and abilities, satisfies children's play needs, provides landscape diversity and multi-purpose elements, and ensures a variety of play scenarios.

The functionality of the playground depends on it achieving the parameters of the stated principle.

Fig. 3 – Playground between apartment buildings or next to them.

Typical of Romanian cities, the playground is close to the children in the neighbourhood. When well-maintained, it is a functional and useful place for the community.

The principles of inclusive playground design

The concept of "universal" or "inclusive" design means that the constitution of products and environments ought to render them usable by all people to the greatest possible extent, without the need for alterations or a specialized design. This includes people of all ages, those dealing with autism, intellectual disabilities, hearing impairments, cerebral palsy, spina bifida, and other mental or physical disabilities, as well as their caregivers. The concept also addresses the needs of other children.

The goal of designing inclusive playgrounds is to maximize each facility's usability by individuals with a wide variety of characteristics.

Whether we are talking about learning strategies or physical space, inclusive design operates according to a distinct set of principles meant to maximize access to and everyone's enjoyment of a space. As with many aspects of our daily lives, one size does not fit all. Well-designed outdoor play environments must include a variety of experiences and be accessible to people with varying skill sets.

Inclusive playground design examines more closely two principles governing universal playground design.

Principle 1: Flexibility in use

Flexible design in inclusive playgrounds means that the design accommodates a wide range of individual preferences and abilities, including low- to high risk-takers. A play aspect that includes adaptable features for a range of users will be the most flexible. For example, interactive elements, such as musical instruments, may be flush with the ground, to walk on or roll over, at a seated height to be touched, or overhead to be reached and to stretch towards. The output should also be varied (e.g., vibration and sound). Interactive features, such as hand bikes and balance beams, can be used in a variety of positions (sitting, standing, on the ground, or on a supporting surface). All interactive features should be mounted or securely attached to a footing so that people can use these elements to move from a sitting to a standing position and vice versa.

Principle 2: Size and space for approach and use

Due to the users' space needs regarding inclusive playgrounds, both in accessing and experiencing the spaces, accommodations for approach, reach and manipulation must be made. Such designs, for example, would provide ample space to park a wheelchair or walker while the child engages with water or in music play. Another example might be that users who are not very steady on their feet may need a larger standing area on the equipment than their more able-bodied peers.

I. Playgrounds design trends

The research analyses three trends in the design of recreational spaces for children.

a) Inclusive Design for All Abilities. Inclusive design means making playgrounds fun and accessible for every child, no matter their abilities. This design helps ensure that children using wheelchairs can play just like everyone else. One example would be the sensory-rich environment, an inclusive playground that has many interesting things to see, touch, and hear, so every child can find something fun to do. These features help ensure that all children play together, making playgrounds a place where everyone feels included and can enjoy themselves;
b) Sustainable Materials and Eco-Friendly Design. Sustainable playgrounds are all about using materials and designs that do not harm our planet. These playgrounds look great and teach children how to care for the environment. Here are some of the incredible ways these playgrounds are helping the Earth: recycled materials - many playgrounds are now built from previously used materials, which helps reduce waste and save valuable resources; biodegradable materials – they break down naturally over time, so they don't harm the environment. Playgrounds using these materials are leading the way in terms of eco-friendly design; water and energy efficiency: These playgrounds are designed to use less water and energy. This is good for the planet and teaches children the importance of saving resources. By focusing on these sustainable practices, playgrounds become a fun place where young people can learn about and practice taking care of the world around them.
c) Inclusive Technology Integration: Accessible and Educational – there's a growing trend of incorporating technology for educational purposes into playgrounds. From interactive learning stations to QR codes that offer historical or educational information, technology is used to enhance the learning experience while ensuring accessibility for all children.

The evolution of playground design continues to push boundaries, with a focus on creating spaces that not only entertain but also nurture creativity, inclusivity, and safety. As designers and communities come together to shape these spaces, the future of playgrounds holds the promise of these environments becoming engaging, educational, and delightful arenas for children's development and enjoyment.

II. A model of urban space transformation

Following the analysis of playgrounds, a model was identified for the landscaping of a measured area of about 3,235 m² (0.3235 ha) encompassing the following facilities: single or double metal or wooden swings, baby swings with special safety supports, slides of different sizes and shapes (including spiral slides, slides integrated into complex play sets), single or double swings, coil spring rocking figures, climbing structures made out of metal or wood, such as climbing walls or climbing towers, fitness equipment adapted for children, such as pull-up bars and balance equipment, benches and tables for parents and children, activity boards to stimulate creativity and learning, water and sand games for sensory development, litter bins and other items of furniture to keep the area clean.

The design of the proposed model comprised the design principles established in the research.

Fig. 4 – Space before fitting out, present condition.

Fig. 5 – Delimitation of the area proposed for planning.

The space is located in the Bistrița Nord area: Suceava Street – Moldova Way – Piața Mică – Shopping Centre (Bistrița Retail Park 1). European road E58 passes through the location.

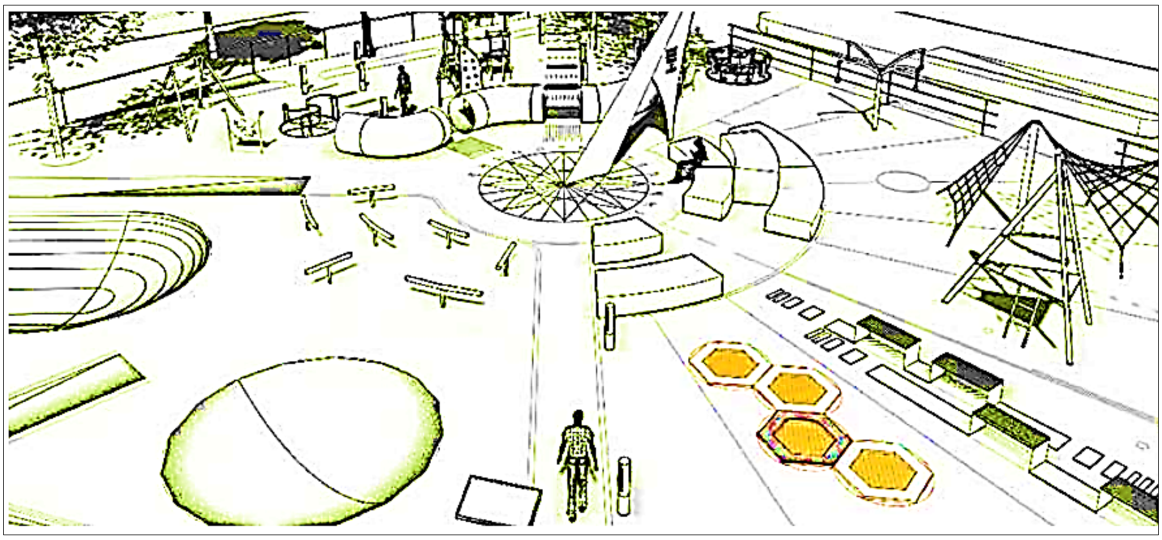

Fig. 6 – Model proposal for playground design.
Source: Alexandru Marius Tătar.

In the area, there is a residential housing development, schools (three high schools), a wholesale market, a church, a shopping centre, bicycle parking, so a children's playground is appropriate for the sustainable development of the city.

The model sketched in Figure 6 is a concept of European, multifunctional, citizen- and community-oriented development.

The development of a playground is important in the development of the quality of life in the urban environment. Another reason why playground development is a priority is the social integration of children through play. The importance of play for development is well documented (Holst, 2017; Stone, 2017). Over the years, many researchers have attempted to define play, and these definitions vary widely. Most researchers agree that play encompasses a combination of characteristics, rather than the presence or absence of a single defining trait (Stone, 2017). Fromberg and Bergen (2006) put forward the following characteristics of play: symbolic, meaningful, active, enjoyable, voluntary, intrinsically motivated, rule-governed, and episodic.

4. CONCLUSIONS

The principles of universal design address more than just usability; designers also must incorporate other considerations — such as economic, engineering, cultural, gender and environmental aspects — into their design processes. The principles described in this research offer designers guidance to better integrate features that meet the needs of as many users as possible.

The analysis of how a children's playground design is experienced allows us to draw the following points:

- Playgrounds are built to meet the needs of children and constitute the effective development of a game environment where unique landscapes and a variety of elements create creative, inventive and emotional games for children;
- The difficult composite structure of the playground enables children to mare their desires and requirements a reality, not only through various physical activities but also through possibility of relaxing in the rather private quiet space.
- The creation and reconstruction of children's playgrounds to increase their aesthetic appeal, becoming aware of the development potential and ensuring compliance with the revealed principles of design of children's game spaces is a requirement.

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ESTIMATIVE OF SOIL LOSSES IN THE PARANAPANEMA RIVER BASIN, SOUTHEAST BRAZIL

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Key-words: erosion, Geographic Information System, control, mapping, Paranapanema River Basin.

Abstract. The Paranapanema River Basin is one of the most important basins in the Centre-South of Brazil, with fertile soils for the practice of agriculture and reservoirs for electricity generation. In the research, the elaboration of a geographic database in the QGIS system was proposed in order to estimate of soil losses using the parameters of the Universal Soil Loss Equation method. Maps corresponding to erosivity, soil types, slopes and land cover in the Paranapanema River Basin were developed in order to define the areas of the plots and generate an average for each factor. Using different tables, averages were obtained by adding the plots of each index to the average from the total area of the watershed. Based on the applied analysis of the Universal Soil Loss Equation, an estimate of 18.13 t/ha/year was obtained, with an estimated sediment production of 302 million tons per year.

1. INTRODUCTION

The phenomenon of soil loss can be quantified through estimates, the methods were improved by the Universal Soil Loss Equation. The latter was developed from the studies of Wischmeier & Smith (1961) using 10,000 data items on soil loss rates in experimental plots on the territory of the United States of America (Laflen & Moldenhauer, 2003). In the USA, studies on soil conservation were the result of 1932's severe wind erosion event, leading to the Department of Agriculture creating a national policy for soil conservation (Bennett, 1972).

Although the intensity of soil loss processes due to water erosion is evident in equatorial and tropical regions, according to Golosov & Walling (2019), only 9% of global estimates of soil losses are from South America and Africa. According to Panagos *et al.* (2022), rainfall erosivity will have increase by 27% by 2050, as a result of climate change.

Soil losses pose a threat to food security and sediments deposition in river plains. The phenomenon of soil loss can occur in areas of preserved forest, but the intensity is many times greater in areas with agricultural crops in soils susceptible to erosion as well as in regions with equatorial climates of heavy rainfall. The erosion of soils caused by agricultural activities represents three times the estimates in relation to natural erosion, reaching 75 billion tons per year (Montgomery, 2007).

In Brazil, soil losses are estimated at approximately 848 million tons per year. The Southeast region of Brazil has the highest rates of soil losses due to dense human occupation and the removal of the vegetation cover. The history of occupation of the Southeast and South regions had be marked by the expansion of coffee crops, including the north of the State of Paraná, between the 1930s and 1970s, with the absence of conservation practices. After the decline of coffee crops, the arable areas were kept only in more fertile soils, such as the nitosol of northern Paraná, with the predominance of the introduction of planted pastures and the action of trampling the herd (Merten & Mirella, 2013).

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The Paranapanema River Basin presents a diversity of natural conditions, with soils highly susceptible to erosive processes, as is the case of Argisols and Cambisols, to very few vulnerable soils such as Nitosols. However, the Paranapanema River Basin has a history of occupation of almost total removal of the original vegetation cover, leaving only the Morro do Diabo state reserve forest, in Teodoro Sampaio and areas of high slopes in the vicinity of Serra do Mar. The northern portion of the Paranapanema River Basin is subject to a large linear erosion, having records of technical and academic works of severe intensities in terms of erosive processes (Tibúrcio, 2021).

The Paranapanema River Basin has an area of more than 10.7 million hectares, distributed between the states of São Paulo and Paraná (Fig. 1). It is one of the main basins of the Paraná River. The economic importance of the territory of the basin is beyond doubt, as it is home to important cities such as Londrina, Maringá, Presidente Prudente, Ponta Grossa, Ourinhos, Itapeva and Itapetininga. Figure 1 shows the location of the Paranapanema River Basin.

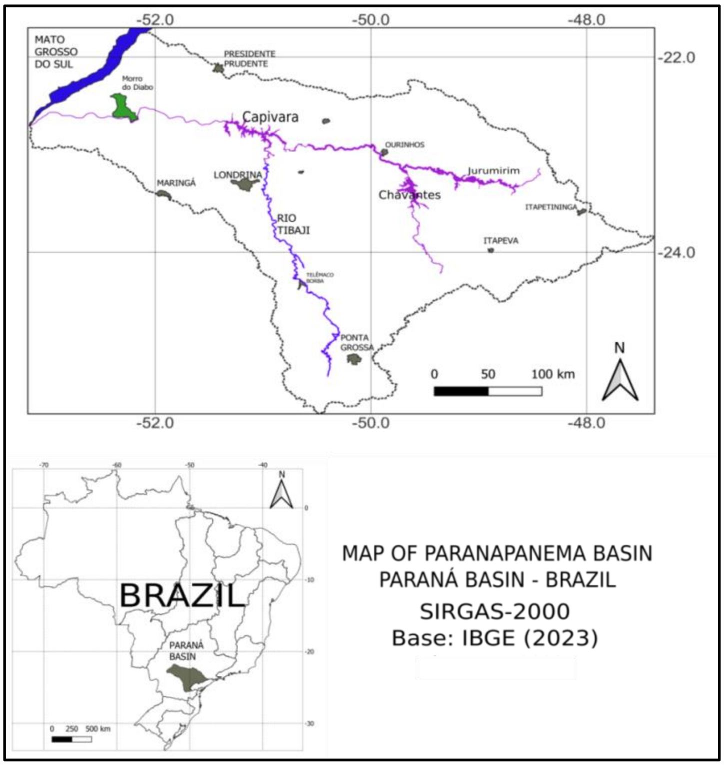

Fig. 1 – Map of Paranapanema's Basin.
Source: Produced by the author (2024).

In addition to the economic activities of food production, such as corn and soybeans in the region of Londrina, the basin has forestry areas used in the pulp industries in the regions of Itapeva and Botucatu, including the production of sugarcane for ethanol in the region of Ourinhos.

The Paranapanema River Basin has large accumulation reservoirs for electricity generation, such as: Capivara, Chavantes, Jurumirim, Taquaruçu and Salto Grande. The development of marginal erosion in the reservoirs can lead to silting, as well as to consequences for the generation of electricity in the Centre-South of the country (Rubio, 2014).

Given these aspects, this study aims to provide an estimate of soil losses through the elaboration of a geographic database for the Paranapanema River Basin, in order to contribute to the production of information that may help present the risks of soil losses for an important territorial segment of Brazil.

2. METHODOLOGY

The methodology was based on the elaboration of a geographic database in the QGIS system, by generating information plans for each factor of the Universal Soil Loss Equation. Each information plan contains the geographic information to be measured by areas, which serves as basis for the analysis and elaboration of the tables regarding the plots. The vectorized information was imported into the geographic database to later be edited for the creation of maps.

In all variables, in order to obtain the factors indices for the Universal Soil Loss Equation, it is necessary to add the values and the ratio of the territorial area in the hydrographic basin.

The estimate of rainfall erosivity was presented based on the data provided by Braido (2015).

The estimation of soil erodibility took into account the parameters presented by Freire *et al.* (1997), Bertol *et al.* (2002) and Bertol *et al.* (2007).

From the data provided by the Shuttle Radar Topography Mission with a treatment performed by the Brazilian Institute of Space Research, a QGIS tool was used to generate the map of slopes.

When calculating the estimation of the LS factor, taking into account the topographic aspects of the Paranapanema River Basin, the parameters presented by Bertoni & Lombardi (1999) were analysed, was the calculation of the average slope in the basin and the ramp length.

The land cover was estimated from the linear design of the areas while using high-resolution remote sensing images available in the Google Earth application, whose files on the polygons of the areas were converted into vector format of the shapefile type. They would then be imported into the QGIS database. The indices of each land cover were adopted according to Bertoni & Lombardi (1999).

3. RESULTS

Table 1 contains the estimate of the rainfall erosivity and the average from the areas of the erosivity classes.

Table 1

Rain erosivity factor (R) in Paranapanema River Basin

Class areas (MJ.mm/h/ha/y)	Area (ha)	R (Class x Area)
7,200	4,806,330	34,605.576
7,800	1,860,000	14,508.000
8,400	2,090,140	17,557.176
9,000	1,709,002	15,381.000
9,600	272,075	2,611.920
∑	10,737,547	84,663,672
	Average (R/Area)	7,884.82

Source: Produced by the author (2024).

The result is the erosivity factor for the Paranapanema River Basin whose value is 7,884 MJ.mm/h/ha/year.

Figure 2 shows the geographical distribution of rainfall erosivity in the Paranapanema River Basin.

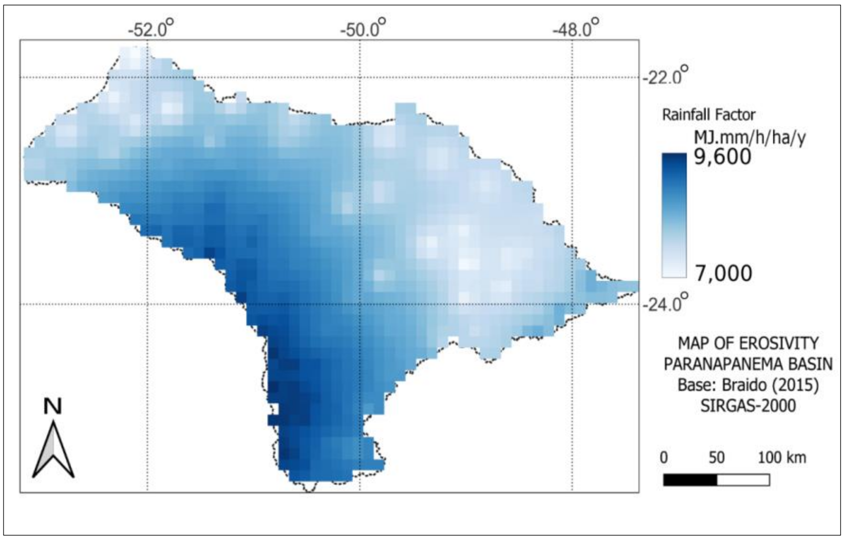

Fig. 2 – Map of erosivity of Paranapanema River Basin.
Source: Produced by the author (2024).

Figure 3 shows the geographical distribution of soils in the Paranapanema River Basin, based on research performed by Oliveira *et al.* (1999) and Larach *et al.* (1984).

The soil erodibility estimate is presented in Table 2, alongside the partial estimates according to soil types, including a synthesis according to the plot average.

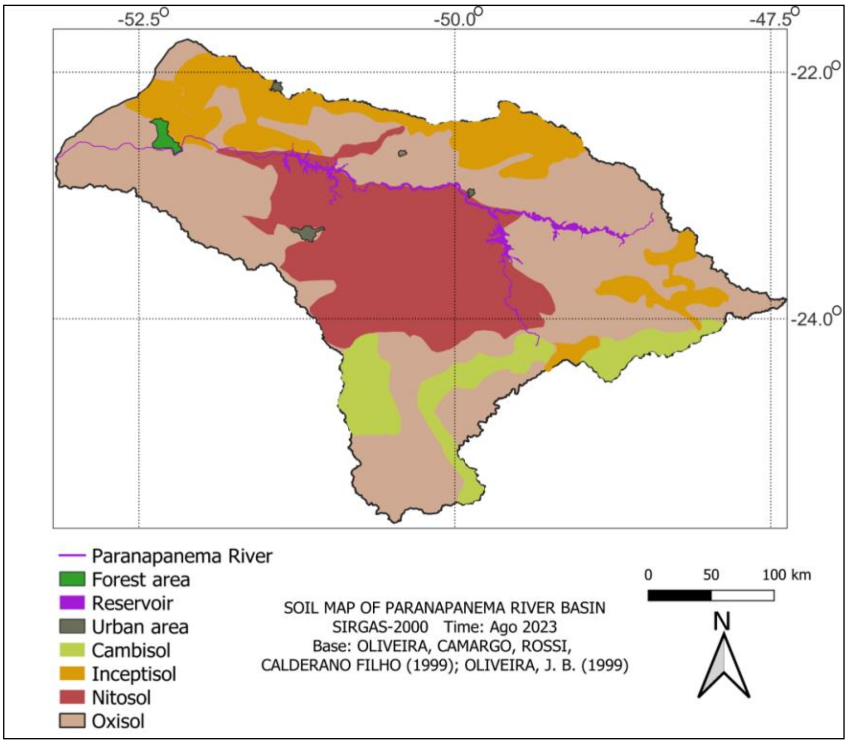

Fig. 3 – Map of Soils of Paranapanema River Basin.
Source: Produced by the author (2024)

Table 2

Factor of erodibility of soil (K) in Paranapanema River Basin

Types of soils	Area (ha)	Index K	K (t/ha/y) (Area x Index)
Inceptsol	1,651,933.3	0.051	84,248.59
Nitosol	2,708,116.2	0.011	29,789.28
Cambisol	909,094.0	0.015	13,636.41
Oxisol	5,468,403.7	0.016	87,494.46
∑	10,737,547		215,168.74
	Average (K/Area)		0.02004

Source: Produced by the author (2024).

Figure 4 shows the geographical distribution of the slopes in the Paranapanema River Basin

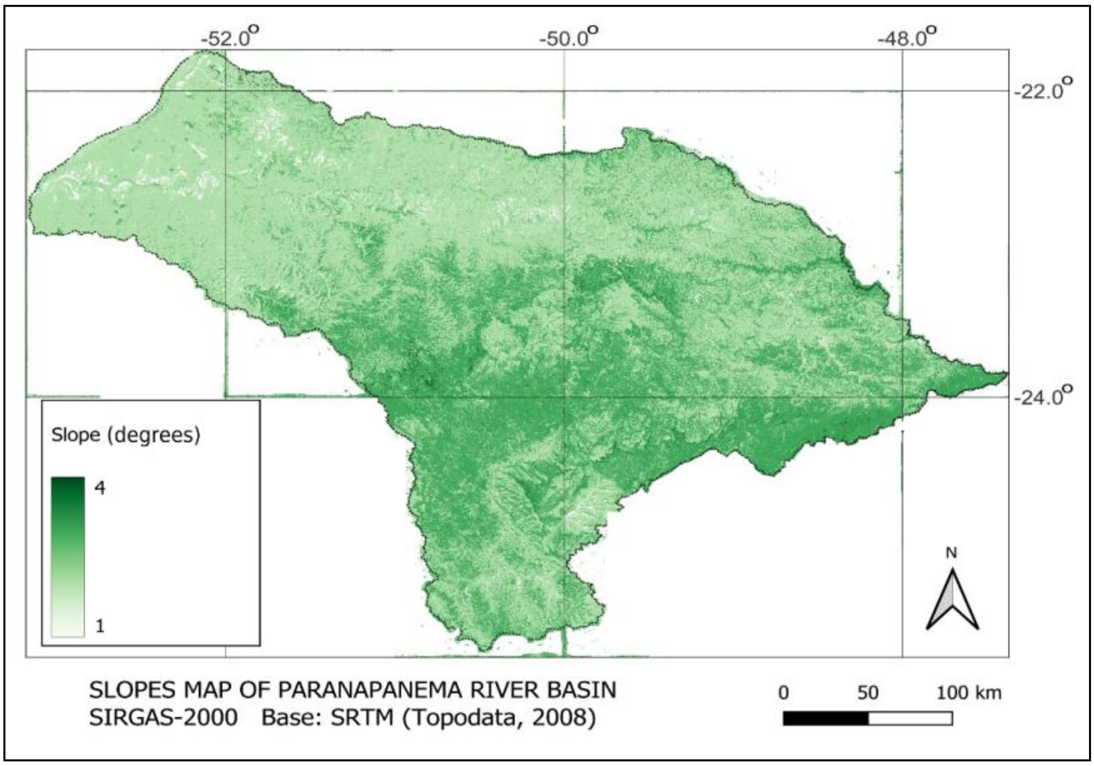

Fig. 4 – Slope Map of Paranapanema River Basin.
Source: Produced by the author (2024).

From the results based on the averages of the soil type plots, the soil erodibility of the Paranapanema River Basin emerges as 0.02 t/ha/year.

If we consider 4.4% as the average slope and 10 meters as the ramp length, the LS factor can be estimated as the following formula:

$$S = 0.00654 \text{ x } 0.044^2 + 0.0456 \text{ x } 0.044 + 0.065 \quad (1)$$

The index was calculated as having the value of 0.67 when the parameters to estimate the LS factor were applied.

Figure 5 shows the geographical distribution of land cover classes in the Paranapanema River Basin.

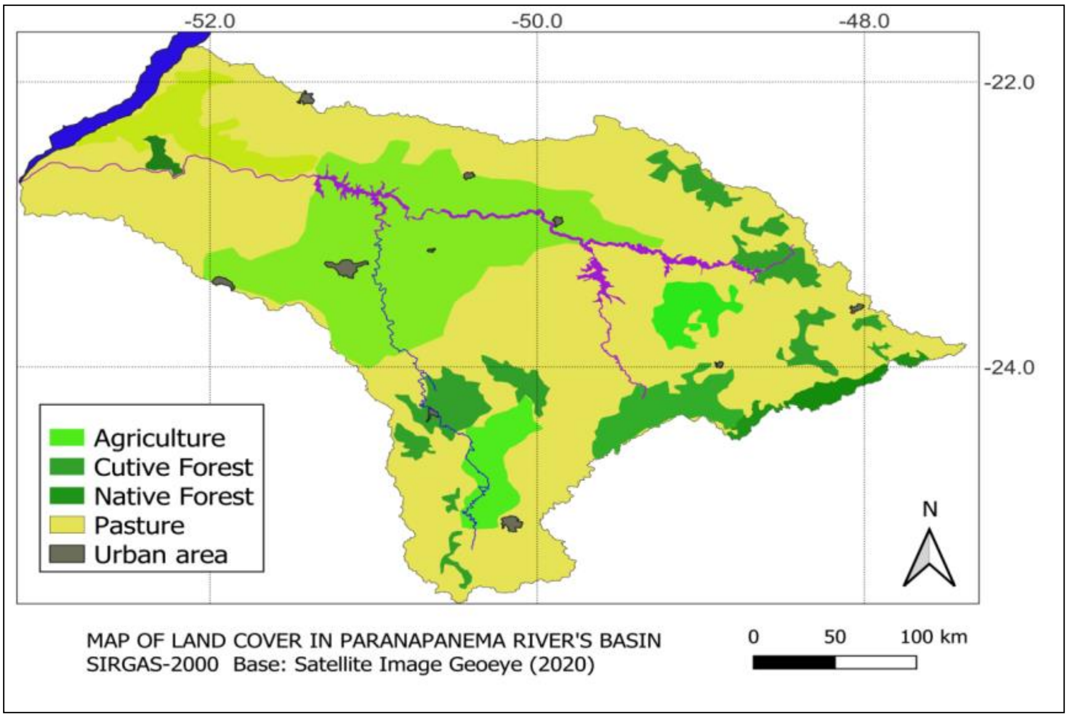

Fig. 5 – Map of Land Cover of Paranapanema River Basin.
Source: Produced by the author (2024).

To obtain the land cover factor (C), the plots of the areas of the land cover classes were calculated according to the Table 3.

Table 3

Factor of land cover (C) in Paranapanema River Basin

Land Cover class	Area (ha)	Index C	C (t/ha/y) (Area x Index)
Agriculture	1,651,933.3	0.11420	340,316.00
Planted forest	2,708,116.2	0.00300	27,605.55
Native forest	909,094.0	0.00003	4.79
Pasture	5,468,403.7	0.37000	2,412,03
∑	10,737,547		2,779,956.33
	Average (C/Area)		0.2589

Source: Produced by the *author* (2024)

The land cover factor for the Paranapanema River Basin was estimated at 0.2589 t/ha/y.

Regarding the factor of conservation practices in the Paranapanema River Basin, approximately 60.7% of the area is made up of pastures land, and about 75% has no conservation practices. In terms of agricultural terrain, which make up about 27.7% of the watershed area, approximately 30% do not have conservation practices. By analysing the territorial areas, we are able to the index of conservation practices index at 0.66.

To conclude, the Universal Soil Loss Equation applied in the Paranapanema River Basin can be expressed as the following formula:

$$A = 7{,}884 \times 0.02 \times 0.67 \times 0.26 \times 0.66 \quad (2)$$

The estimated water erosion rate for the Paranapanema River Basin was 18.13 t/ha/year.

When considering the total area of the Paranapanema River Basin, the soil loss is 194,671,727 tons per year.

When considering that the density average soil in the Paranapanema River Basin is 1.55 t/m^3 (Oliveira, 1994), the estimated sediment production is 302 million tons per year.

4. DISCUSSIONS AND CONCLUSIONS

The Paranapanema River Basin has more than 10 million hectares, a diversity of soils, meteorological and hydrological conditions, including changes in agricultural practices since the beginning of territorial occupation with the planting of coffee in the 1920s. Starting in the 1970s, many pasture areas were replaced by sugarcane plantations and the urban expansion.

In the northern part of the Paranapanema River Basin, despite having lower rainfall with lower erosivity, the erosion processes are more intense. The territorial areas to the north stand out the proximity of the city of Marília, with very sandy soils, as well as the region of the city of Presidente Prudente. In the case of the southern areas of the Paranapanema River Basin, the clayey soils maintain a low erodibility rates, thus registering a lower loss of soil, despite a history of higher rainfall volumes, as is the case of the sub-basin of the Tibagi River, near the city of Londrina.

The Paranapanema River Basin has hydroelectrics, due to the large flow of the plateau rivers. Large areas were flooded to form reservoirs for hydroelectric power plants, leading to biodiversity losses and submerged soils.

When discussing the analysis of the results of the application of the Universal Soil Loss Equation, it is mainly rural erosion that stands out, with the production of sediments that can silt up the reservoirs of hydroelectric plants and generate future problems for the energy matrix as well as losses of resources providing water.

Although the Universal Soil Loss Equation is a method that has been applied since the 1970s, there are few applied research in Geography, whose spatial analyses of geoprocessing contribute to scientific improvement.

The estimation of soil losses entails the geographical analysis of the climatic aspects of the erosivity factor, the pedological aspects of the erodibility factor, the relief conditions of the topographic factor and the land cover changes, which are topic frequently addressed by geographers.

The research contributes by providing the cartographic analysis of soil erosion's influencing factors, using geographic information system in a database to generate cartographic documents. Cartography, together with the existence of a geographic database contributes to the application of a policy for soil zoning and for avoiding the deforestation of new areas, in addition to the implementation of conservation practices in the altered areas.

The research may advance in the terms of production of land cover maps for different periods, as well as in terms of the applications of the estimates regarding studies on surface runoff and water erosion.

Soil conservation in the Paranapanema River Basin requires a policy to help temper land use, promote the recovery of deforested areas, the implementation of policies for water resources management units. The loss of soils equates to food and energy insecurity, since soil is a finite natural resource, which requires on hundreds of years to recover and maintain its fertility for the development of life.

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L'ÉVOLUTION DIACHRONIQUE DES INTÉRACTIONS URBANISATION / COURS D'EAU. CAS DE LA VILLE DE BEJAÏA (LITTORAL ALGÉRIEN)

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Mots-clés: évolution urbaine, cours d'eau, anthropisation, altération, Béjaïa, Algérie.

The diachronic evolution of the urbanization/riverways interactions. The case of the city of Bejaïa (the Algerian Coast). In the Mediterranean city of Bejaïa, the urban phenomenon has had, over the centuries, certain repercussions on the natural spaces, in particular those of the river environments, which are numerous in this city. This work aims to study this phenomenon from two perspectives, namely the geographical and temporal space. Spatial urban interventions in Bejaïa represent the material to be studied; as for time, it is considered the unit of measurement of urban evolution and the changes it causes to rivers. Thanks to a geo-historical method, we will direct our research towards the exposure of the influences exerted by the urban phenomenon on the waterways of the study area, from the creation of the city to present day. The objective of this theoretical presentation is to summarize the transformations of the links between urbanization and the hydrology of the study area.

1. INTRODUCTION

L'exploration des liens entre l'urbanisation et les milieux fluviaux est devenue un sujet de recherche très fréquent ces dernières années, en particulier après la prise de conscience de l'importance de l'écologie, de l'environnement et de la lutte contre le réchauffement climatique, ainsi que des risques naturels et anthropiques qui en découlent. Aujourd'hui, et grâce aux différents travaux scientifiques qui en avaient fait la description (Walsh *et al.*, 2005; Wong et Brown, 2009), les altérations dues à l'action de l'Homme sur les cours d'eau urbains sont bien connues.

En Algérie, les recherches menées dans ce sens se concentrent principalement sur les effets de la pollution des eaux de surface ou des eaux d'assainissement sur la santé des résidents et la qualité de vie en milieu urbain. Concernant la ville de *Béjaïa*, de nombreux chercheurs de différentes disciplines se sont intéressés à cette problématique. Ils ont pris pour cas d'étude les effets des rejets industriels sur la qualité hydrologique et biologique du fleuve de la *Soummam* (Bacha et Amara, 2007; Mouni *et al.*, 2009; Zouggaghe et Moali, 2009).

Cependant, les disfonctionnements dans le système hydro-urbain ne se limitent pas qu'à la qualité des eaux de la Soummam. D'autres facteurs interfèrent au fil du temps avec l'équilibre ou le déséquilibre de ce système. Ces facteurs proviennent des changements créés par la croissance urbaine et s'identifient sous deux aspects initiaux: l'espace et la société (Le, 2016).

Ce travail porte sur les services fluviaux et leur relation avec l'urbanisation de la ville de *Béjaïa*. L'objectif est donc d'identifier et de théoriser le type de relation qui existe entre le phénomène urbain et les différents cours d'eau, qui se sont développés au fil du temps et de l'espace dans la ville de *Béjaïa*.

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2. MÉTHODOLOGIE

2.1. Le cas d'étude

Elle fait partie de la région de la Petite Kabylie, située au centre-est de la côte algérienne, sur la rive sud de la Méditerranée, et se trouve à 220 km à l'est de la capitale Alger. *Bejaïa* forme un amphithéâtre d'un axe long d'environ 5 km. Elle est entourée par les montagnes: *Boudarham*, *Gouraya* et *Boukhantouche* à l'Ouest, au Nord et, respectivement, au Sud et s'ouvre sur la mer par une plaine maritime à l'Est (Fig. 1).

Coordonnées géographiques: 36° 45′ 00″ Nord et 5° 04′ 00″ Est.

Bejaïa est une ville de taille moyenne en termes de population et de superficie occupée. Elle a une superficie de 120,22 Km² avec une population estimée en 2019 à 191 936 personnes (Annuaire statistique de Bejaïa, 2020).

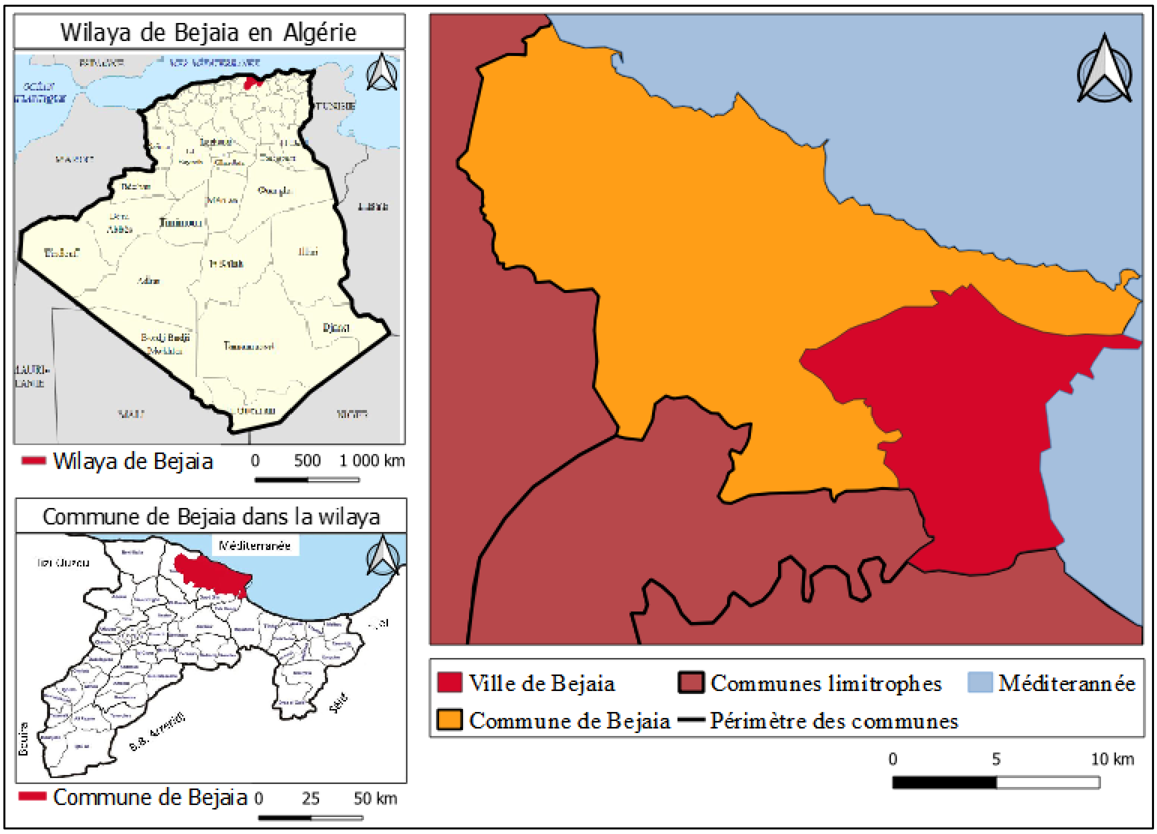

Fig. 1 – Situation géographique de *Bejaïa.*
Source: Boukhiar, Boutabba et Medjadj, 2023, sur fond de cartes Google Maps.

La ville draine deux bassins fluviaux, le *Cap-Sigli* et la *Soummam*, qui dépendent du bassin côtier *Algérois* pour le premier, et celui de la *Soummam-Hodna*, pour le second.

La zone présente des caractéristiques typiques du climat méditerranéen: les hivers sont doux et humides et des étés sont secs et chauds. Elle est aussi une des endroits les plus humides en Algérie, où les précipitations peuvent dépasser 1000 mm/an. Sa topographie façonnée par les montagnes aux alentours joue un rôle important dans la condensation des vapeurs atmosphériques et la formation des précipitations et l'alimentation des rivières.

C’est l’une des régions les plus humides d’Algérie, mais elle reste sensible au stress hydrique comme pour l’ensemble de la région de l’Afrique du Nord, en raison des effets du réchauffement climatique et des interventions humaines.

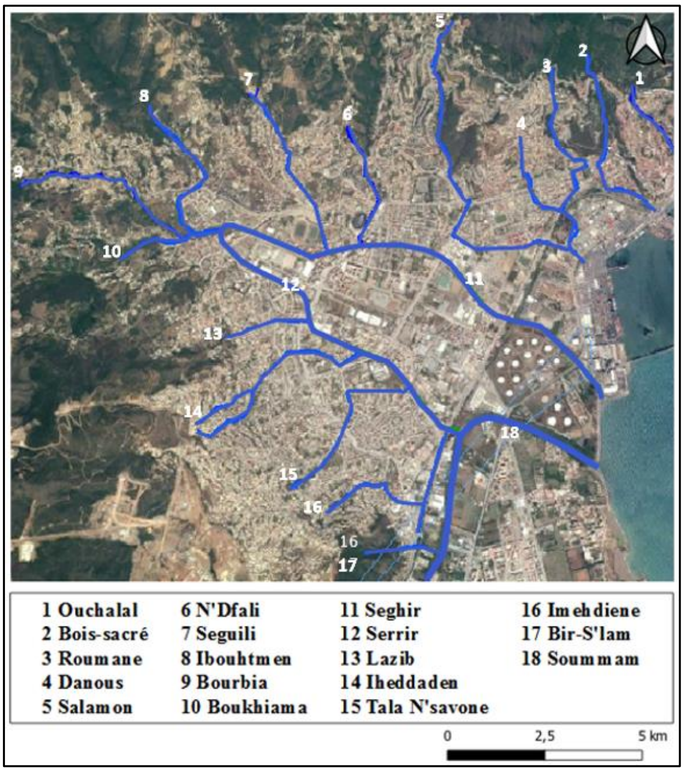

Fig. 2 – Le réseau hydrographique de la ville.
Source: Boukhiar, Boutabba et Medjadj, 2023, sur fond de carte Google Earth. Consulté le 14/03/2023.

Les principales caractéristiques du réseau hydrographique de *Bejaïa* sont synthétisées dans le tableau suivant (Tableau 1).

Tableau 1

Principales caractéristiques du réseau hydrographique de Bejaïa et ses sous-bassins versants

Rivière	**1.Ouchalal**	**2.Bois-sacré**	**3.Roumane**	**4.Danous**	**5.Salamon**	**6.N’dfali**
Etat du talweg	Canalisé Couvert	Canalisé Couvert	Canalisé Couvert	Canalisé Couvert	Naturel Canalisé Couvert	Naturel Canalisé Couvert
Nature du sous bassin	Urbain Rural	Périurbain Rural	Périurbain Rural	Urbain	Périurbain Rural	Urbain Rural
Occupation du sol	Logements	Logements	Logements	Logements	Logements	Logements
Rivière	**7.Seguili**	**8.Ibouhatmen**	**9.Bourbiaa**	**10.Boukhiama**	**11.Seghir**	**12.Serrir**
Etat du talweg	Naturel canalisé Couvert	Naturel Canalisé Couvert	Canalisé Couvert	Canalisé Couvert	Naturel Canalisé Couvert	Canalisé Couvert
Nature du sous bassin	Périurbain Rural	Périurbain Rural	Périurbain Rural	Périurbain Rural	Urbain Périurbain	Périurbain
Occupation du sol	Logements	Logements	Logements	Logements	Industrie Commerce Logements	Industrie Commerce Logements

Tableau 1 (continué)

Rivière	**13.Laazib**	**14.Iheddaden**	**15.T.N.S.**	**16.Imehdiene**	**17.Bir S'lam**	**18.Soummam**
Etat du talweg	Naturel Canalisé Couvert	Canalisé Couvert	Naturel Canalisé	Canalisé Couvert	Naturel	Naturel
Nature du sous bassin	Périurbain Rural	Périurbain	Urbain	Urbain	Périurbain Naturel	Périurbain Naturel
Occupation du sol	Logements	Logements	Logements	Logements	Logements	Industrie Logements

Source: Boukhiar, Boutabba et Medjadj, 2023.

2.2. Méthodologie d'approche

Pour le présent travail, nous avons adopté une approche géo-historique, qui exploite des sources écrites officielles et officieuses. Les sources historiques étayant les périodes anciennes sont rares, nous avons mis à profit les ouvrages d'historiens et des voyageurs (Ibn Khaldoun, Léon l'Africain, Al-Bakri). La période des différentes colonisations, notamment Française, s'est consolidée par les rapports de Sénatus Consulte, des plans d'alignement de la ville, ainsi que différentes cartes cadastrales.

Pour documenter le thème lié à l'urbanisation depuis l'indépendance, nous avons utilisé les données collectées dans le cadre de nos travaux de recherche ainsi que les rapports d'expertise et les plans des organismes officiels: Office national d'assainissement (ONA) et Office national des statistiques (ONS).

Toutes les données rassemblées ont fait l'objet d'intégration dans les outils SIG (QGIS 3.16.0) et Global Mapper (21.0), pour l'interprétation des données en cartes thématiques.

3. RÉSULTATS ET DISCUSSIONS

3.1. Étapes d'évolution dans le temps du phénomène urbain de la ville de Bejaïa

3.1.1. Urbanisation de Bejaïa durant les périodes antique et médiévale: une ville compacte intramuros

Les premières traces de présence humaine à l'emplacement de l'actuelle ville de *Béjaïa* remontent à la plus Haute Antiquité (Gaid, 1991), où des vestiges archéologiques datant de plus de 200 000 ans à 10 000 ans ont été retrouvés sur le site.

L'origine de la fondation de la ville remonte à l'époque *numide* (VI^{e} siècle av. J.-C., jusqu'à 33 av. J.-C.) et les sources existantes l'associent au territoire du royaume de la *Numidie Massaessyle*, puis au royaume *numide* de *Massyle* (Feraud, 2001), où elle fut l'une des huit ateliers de création de monnaie du dernier royaume.

À partir de 33 av. J.-C., les Romains envahirent la région et s'emparèrent de la baie de *Béjaïa*, qui devint la ville *numido-romaine* de *Saldae*[2], et ce, jusqu'en 429 ap. J.-C. Cette ville fut dotée de certains équipements: forums, aqueducs, bains, ainsi qu'un mur d'enceinte de circonférence de 3 000 m (Benazzouz, 2009).

Au Moyen Âge, l'état chaotique de la ville fut surmonté par l'établissement de la dynastie des *Hammadides* en 1091. Le paysage urbain fut marqué par des espaces moins défensifs et plus ouverts, (Aouni, 2014), conférant à la ville prospérité et le statut de leader en Méditerranée, en Afrique et en terre d'islam. Elle connut également le règne des dynasties *almohades (1152–1228)* et *hafsides* (1228–1510). Les premiers construisirent la *Casbah*, une forteresse de plus de 20 000 m^2, composée de plusieurs bâtiments, dont une mosquée, une école et une porte principale (Fig. 3).

[2] Du nom local « *Aselden* »

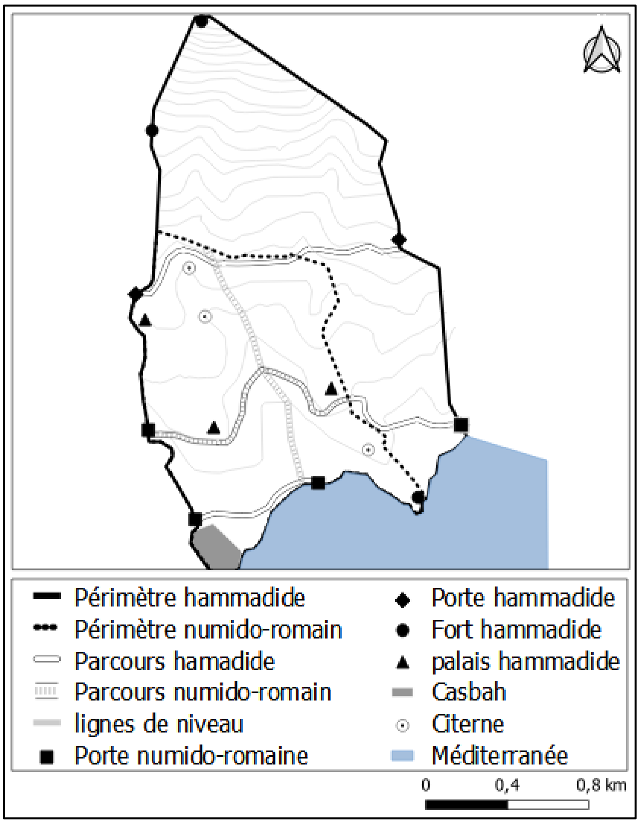

Fig. 3 – Essaie de restitution du tracé de la ville de *Bejaïa* entre 33 av. J.-C. et 1510.
Source: Boukhiar, Boutabba et Medjadj, 2023, sur base de fond de carte de *Bejaïa* d'après Gsell (1947).

A ces époques, Léon L'Africain parle d'une cité assez bien équipée et évoque des hospices, des hôtels, des hammams et marchés, tous étant de bonne facture et esthétiques (Léon l'Africain, 1956).

3.1.2. Urbanisation de Bejaïa durant les périodes de colonisation, la ville en décadence urbanistique.

Après le déclin des dynasties locales, vers 1509, de nombreux quartiers furent abandonnés, et l'enceinte de la ville réduite en surface et en nombre d'habitants. Selon Feraud, 2001, la superficie de la ville a diminué jusqu'au tiers de sa superficie durant la période *hammadide*, les monuments ont été détruits et la population a diminué jusqu'à 4 000 habitants, voire 2 000 habitants (Feraud, 2001). De même, les équipements, hormis ceux voués à la défense, furent détériorés. Les traces de cette époque laissent à penser qu'il n'y avait pas de ville à l'emplacement de *Bejaïa*, vue qu'elle fut citée sous le nominatif de port et pas de ville (El-Bakri, 1992). Cette décadence se prolongea jusqu'en 1555. Dès lors, la ville devient un simple point de défense (Fig. 4).

La seconde entité urbaine, encore visible aujourd'hui dans l'ancienne ville, représente la ville fondée par étapes de 1833 à 1962. En premier lieu, il y eut une intervention de fortification des défenses de la ville de 1833 à 1848 par la restauration des édifices déjà existants. Vint ensuite, la densification intra-muros de la ville existante de 1848 à 1891. À partir de 1891 et pour la première fois dans son histoire, la ville dépasse ses limites historiques pour une extension extra-muros, vers la plaine. Cette extension a été initiée après la destruction de la partie ouest du mur d'enceinte historique et a utilisé deux éléments de l'aménagement pour se repérer: le tracé agricole et le tracé viaire de l'axe *Biziou* (Korichi, 2011). Cette période marque la rupture avec la ville historique et le début d'une nouvelle ère d'urbanisation, qui donne naissance à la ville étalée, que nous étudierons dans la section suivante (Fig. 5).

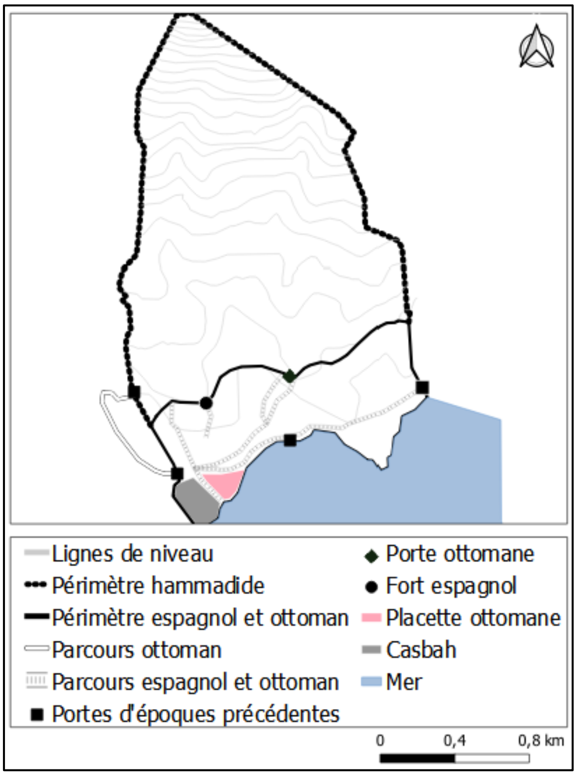

Fig. 4 – Essaie de restitution du tracé de la ville de *Béjaïa* entre 1510 et 1833.
Source: IDEM.

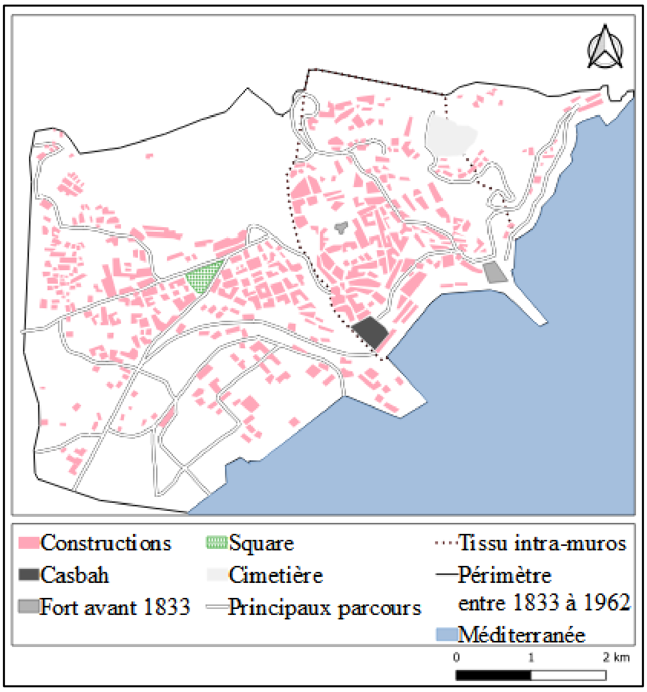

Fig. 5 – Essaie de restitution du tracé urbain de la ville de *Béjaïa* entre 1833 et 1962.
Source: Boukhiar, Boutabba et Medjadj, 2023, sur base de fond de cartes cadastrales de *Bejaïa* (1891, 1920, 1962).

3.1.3. Urbanisation de Bejaïa à partir de la deuxième moitié du 20e siècle jusqu'à nos jours: une ville étalée au détriment de la plaine

Tout comme les villes algériennes subissent la pression d'une urbanisation rapide (Saada et Dekoumi, 2019). L'urbanisation de *Béjaïa,* à cette époque, était rapide et incontrôlée et se caractérise par deux formes urbaines: la première, planifiée, exécutée par l'État et la seconde, spontanée et auto-réalisée par les habitants.

3.1.3.1. L'urbanisation planifiée postindépendance

La planification a rompu avec l'urbanisme de l'ilot d'avant l'indépendance. Elle se caractérise par une rupture fonctionnelle, structurelle et morphologique (Aouni, 2014), et se distingue par l'absence « *d'un modèle urbain et d'une référence architecturale* » (Idem), ou par une stratégie spatio-aménagiste et socio-économique (Belkhiri, 2009). Nous retenons trois étapes principales: la première incarne la volonté d'industrialisation accélérée et intense du pays de 1964 à 1979. La deuxième se focalise sur la construction rapide des logements au cours de la période 1980 à 1999. La troisième concerne une organisation de l'espace guidée par les principes de l'économie du marché, depuis le début du siècle jusqu'à nos jours.

Au début, la forme d'urbanisation était guidée par une politique d'urbanisme de zonage, inspirée du modèle soviétique (Boutabba, 2001), créant des zones monofonctionnelles. La logique du zonage provoque la perte de la notion de l'espace public spécifiquement défini (Benazzouz, 2009). Dans ces zones, les fonctions de liaison, des aménagements de récréation et des équipements de proximité sont entièrement supprimées de l'espace urbain. Cela rend cet urbanisme modeste en termes fonctionnel et esthétique (Bouaifel, 2010). L'extension planifiée eut lieu, principalement, dans la plaine, mais aussi dans les hauteurs de *Sidi-Ahmed* et *Iheddaden*, abritant des ZHUN[3] du même nom.

Depuis la décade des années 2000, l'extension urbaine de la ville de *Béjaïa* se résume en trois principaux points: l'engloutissement de la *Soummam* par l'urbanisation de ses berges; l'extension linéaire exogène vers le Sud et l'Ouest le long des routes nationales (RN) (Fig. 6).

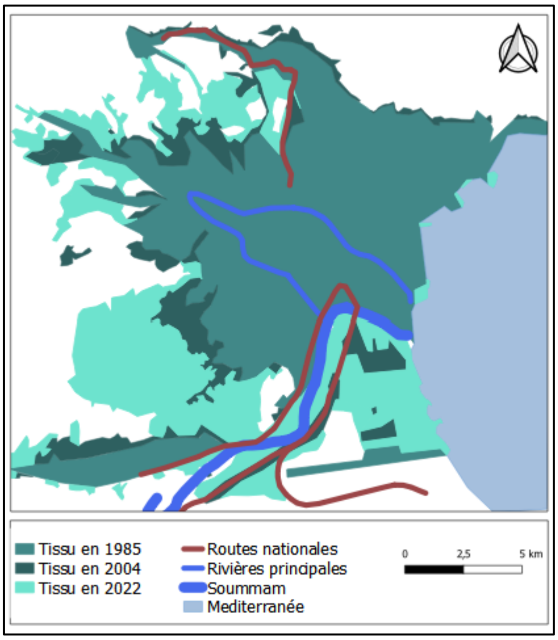

Fig. 6 – L'extension de la ville après l'indépendance.
Source: Boukhiar, Boutabba et Medjadj, 2023, sur fond de cartes Google Earth, consulté le 13/03/2023.

[3] Zone d'Habitation Urbaine Nouvelle.

3.1.3.2. L'urbanisation spontanée postindépendance

L'urbanisation dans ce contexte est une auto-intervention pacifique et tolérée par les autorités. Le caractère spontané fait référence à l'absence de toutes les procédures architecturales, urbanistiques, techniques, juridiques et sécuritaires nécessaires à l'acquisition des terrains et à l'implantation des constructions. Les zones d'extension spontanée sont de deux types différents: le spontané salubre et les bidonvilles.

Dans le premier cas, le tissu se présente sous forme de pavillons, d'immeubles à plusieurs étages et de villas, tous de type individuel et situés sur les hauteurs à la périphérie de la ville. C'est le cas des lotissements d'*Amtik, Amtik-N'tafat, Boukhiama, Ibourassen, Ighil-Ouamriw, Ighil-Ouatou, Ighil-Ouazoug, Taassast, Taklait, Takhribt, Takhrouit-N'Cham, Taghzouit, Tala-Markha, Tala-N'savone, Targua-Ouzemour, Tazeboudjt et Tizi*. Ce type d'urbanisation représente une partie importante du parc de logements de la ville (Fig.7). Le tissu est très dense, et peut être qualifié de périurbain ou de rural (Kheladi *et al.*, 2001).

Un autre tissu moins dense, car composé de constructions dispersées poussées sur le littoral, principalement sur la côte ouest, et sur le plateau de *Sidi-Boudarham*. Dans le second cas, d'autres structures à faible densité sont constituées de constructions éparses et réparties le long du littoral, principalement sur la côte ouest et le plateau de *Sidi Boudarham*. Dans ce sens, des dizaines de projets de constructions illégaux sont enregistrés chaque année (DPSB, 2015). Une fois achevé, ce tissu fait généralement l'objet de régularisation ou de démolition, conformément à la loi 08/15.

Dans le deuxième cas, ce sont des bidonvilles façonnés à partir de matériaux de récupération rudimentaires et inadaptés à la construction, souvent dangereux pour la santé humaine et pour la bonne qualité des espaces naturels. Ces constructions sont en nombre ne dépassant pas des centaines[4] (DUC, 2016). Elles sont situées dans la ville nouvelle de *Sidi-Ali-Labher*, la cité *Soumari*, la cité *Eucalyptus* et la cité *Base Impros* (Fig. 7).

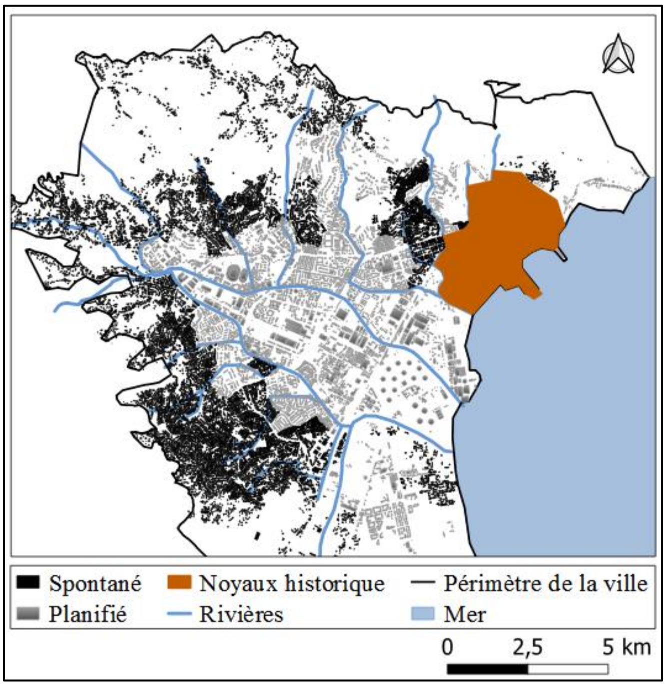

Fig. 7 – L'urbanisation spontanée postindépendance.
Source: IDEM.

[4] 247 logements recensés en 2016 (DUC, 2016).

3.2. Type et nature des liens urbanisation / cours d’eau à *Béjaïa*

3.2.1. Les cours d’eau aux époques antique et médiévale: une forte relation symbiotique avec le fait urbain

A défaut d’existence de sources, nous ne savons pas grand-chose sur la place de l’eau pendant les époques antiques. Néanmoins, les auteurs qui en parlent semblent s’accorder sur le fait que l’alimentation en eau s’effectue par deux moyens: par voie d’exploitation des sources et des cours d’eau présents sur le territoire, et par récupération des eaux de pluies à titre individuel dans les habitations, comme ce fut la pratique dans toute la méditerranée (Djermoune et Felah, 2018).

Dans la cité de *Saldae*, l’eau était placée à hors des murs de la ville. Pour desservir les bains, les fontaines et les différents équipements à l’intérieur des murs de la ville, il existait des citernes alimentées par les sources et les rivières, au début. Par la suite, deux aqueducs ont capté les eaux des monts *Gouraya,* à 530 m, au nord de la ville, et du mont *Adrar Aghbalu,* situé à 16,5 km à l’ouest.

Les cours d’eau constituèrent l’élément clé de la planification urbaine de l’époque. En effet, si le *« Cardo Maximus »* est, selon Gsell (1913), tracé parallèlement aux courbes de niveau de la ville, le *« Documanus »* lui se superpose à sa principale rivière. De même pour les réservoirs d’eau, tous aménagés à proximité des rivières.

À l’époque médiévale, le lien de la ville avec ses eaux était plus évident qu’aux époques précédentes. Outre l’élan commercial qu’a connu son port, les écrits suggèrent que le fleuve de la *Soummam* était dédié au transport par bateau (El-Bakri, 1992).

À l’image des villes médiévales algériennes (Boutabba *et al.*, 2019), le tissu urbain sinueux et dense de *Béjaïa* suit parfaitement le chemin de ses cours d’eau. Ces derniers étant utilisés comme tracés régulateurs, essayant au mieux, de respecter la logique des surfaces cultivables. La production et l’extension d’espaces s’est faite selon les éléments structurants naturels des cours d’eau et de la topographie. Ceci laisse à voir une adaptation de l’humain et de son entité urbaine aux éléments naturels des cours d’eau.

Durant la colonisation espagnole et ottomane, la décadence urbaine s’est reflétée sur l’usage et la bonne exploitation des eaux. Les réalisations hydrauliques furent reléguées au second plan, puisque la raison d’être de la ville, qui jadis assurait son rayonnement économique par le port, fut abandonnée. Les fameux aqueducs qui alimentaient la ville et les fontaines publiques furent délaissés. Les nombreuses citernes, bains publics, ainsi que le système d’irrigation ont tous connu le même sort.

3.2.2. Début des altérations anthropiques sur les cours d’eau : une action au lendemain de la colonisation française

Le nouveau système d’assainissement aux motivations hygiéniques, transforma les rivières en exutoires d’eaux chargées de substances polluantes organiques et minérales diverses. Tel est le cas de la rivière *Ouchaalal*, qui constitue l’exutoire des quartiers *Amimoun, Lacifa, Karaman* et *Bab-L’ouz*. Pour contrer les soucis sanitaires, comme c’était couramment le cas à cette époque, ces cours d’eau ont été altérés encore davantage par une intervention physique, plus marquante. Ainsi, *Ouchaalal,* la principale rivière de l’ancienne ville, a fait l’objet d’enterrement. Au sud de la ville, le premier pont qui permet de traverser la *Soummam* fut construit (Colin-Mansuy, s. d.).

Par ailleurs et afin de libérer le foncier au profit de réalisation de grands projets urbains, certaines interventions de drainage de la plaine, (Espérou, 2010), de recalibrage et de déviation des cours d’eau ont eu lieu. La rivière *Serrir,* la plus grande rivière de la plaine après la *Soummam,* a fait ainsi l’objet de déviation en vue d’aménager le premier aérodrome de la ville. La déviation a consisté au déroutement de la *Serrir* et à sa réorientation vers le lit de la rivière *Laazib,* aux deux emplacements de l’actuelle cité *Laazib-Oumamar* au nord et *Bir-S’lam* au sud. Sur une distance de 1,8 km (Fig. 8) le tracé naturel de la *Serrir* a donc été asséché sur 1,3 km de distance. Désormais, elle rejoint la rivière *Seghir* au confluent du quartier spontané de *Targua-Ouzemour* au nord-ouest, et la rivière de la *Soummam* à *Bir-S’lam* au sud.

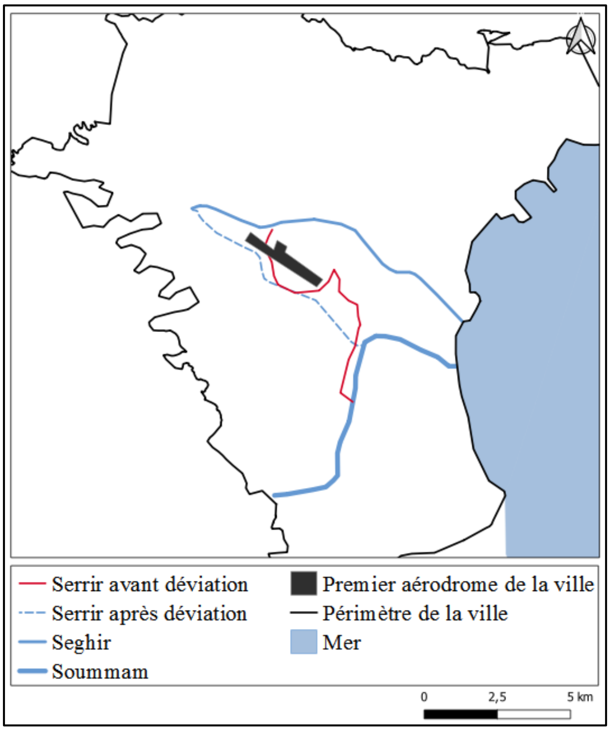

Fig. 8 – Déviation de la rivière *Serrir*.
Source: Boukhiar, Boutabba et Medjadj, 2023, par superposition des fonds de cartes de *Bejaïa*, d'après la DSA (2005), carte d'état-major (1985).

3.2.3. Altération substantielle des cours d'eau à Bejaïa: la planification urbaine post indépendance attire particulièrement l'attention

Les altérations des cours d'eau dans le contexte de ce type d'urbanisme se manifestent sous deux aspects: la création de l'environnement bâti en lui-même et la pratique des activités au seins de cet environnement bâti.

La création du cadre bâti, qui n'est soumise à aucune règle technique visant à protéger les espaces naturels ou la sécurité humaine, a conduit à des empiètements physiques sur tous les cours d'eau que compte la ville. Lors des interventions urbaines réalisées à cette époque, les cours d'eau ont été altérés de différentes manières, principalement physiquement et morphologiquement, par différents moyens: recouvrement, canalisation, aménagement d'ouvrages, déviation, construction de berges et de lits.

La construction dans les périmètres du domaine hydraulique public (DHP) est désormais une pratique banalisée par son intensité et sa généralisation, au point qu'aucun cours d'eau n'y échappe.

L'urbanisation illicite est la première cause responsable de ce phénomène, mais pas la seule. L'urbanisation planifiée compte également des dépassements dans ce sens. À titre d'exemple: la polyclinique du quartier *Ouchaalal* traverse le lit mineur de la rivière du même nom; la salle de prière dans une mosquée du quartier *Iheddaden* traverse le lit mineur de la rivière *Laazib*; un cimetière est implanté sur le lit de la rivière du *Bois Sacré*; …etc. (Fig. 9).

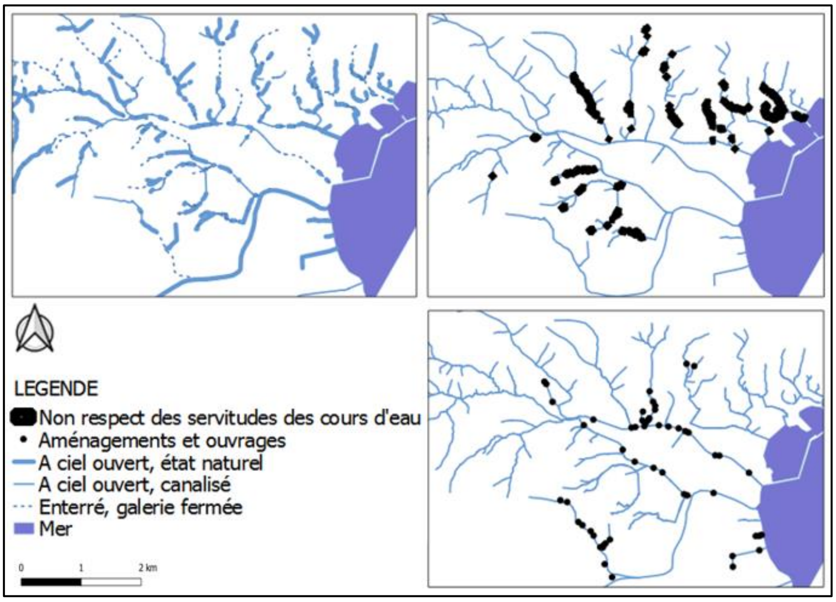

Fig. 9 – Altérations physiques des cours d'eau urbains de la ville de *Béjaïa*.
Source: Boukhiar, Boutabba et Medjadj, 2023, sur la base de données numériques de l'office national d'assainissement (2017).

De l'autre côté, les activités socioéconomiques de la ville ont un impact notable sur les cours d'eau à travers le rejet de déchets, tant solides que liquides. C'est un fait que tous les cours d'eau de la ville sont affectés par les raccordements illicites d'eaux usées (Office national d'assainissement 2017). Il s'agit malheureusement d'une pratique appliquée par les particuliers, dans le cadre de l'urbanisation spontanée, comme par les acteurs urbains et économiques, qu'ils soient publics ou privés. Au fait, ces rivières sont prises pour de simples déversoirs, pour tous les types d'eaux usées: ménagères, industrielles et municipales (Fig. 10).

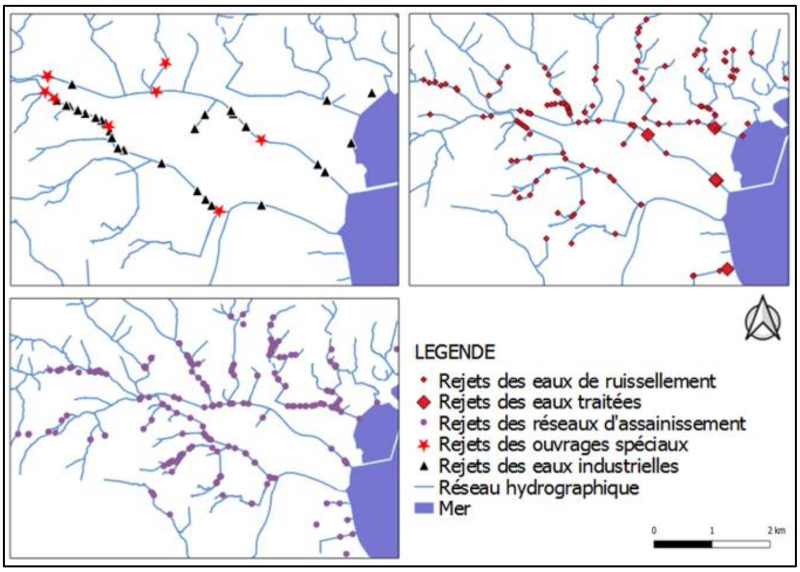

Fig. 10 – Points des rejets liquides vers les cours d'eau.
Source: IDEM.

A ce sujet, 28 points de rejets industriels vers les cours d'eau sont identifiés. Les rivières les plus touchées sont *Serrir* et *Seghir*, situées au centre du tissu urbain.

Le schéma suivant identifie le nombre des usines responsables des rejets d'eaux usées dans les cours d'eau. Les rejets se font soit directement vers les cours d'eau, soit indirectement, par l'intermédiaire du réseau d'assainissement semi-unitaire de la ville (Fig. 11).

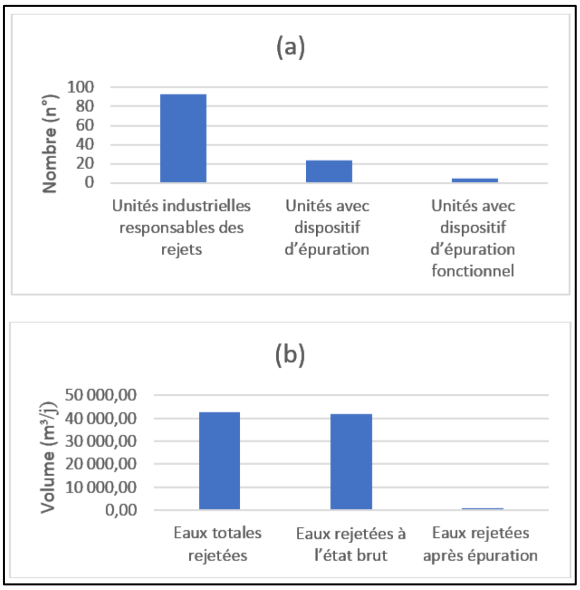

Fig. 11 – (a) Nombre des usines responsables des rejets, disposant et non disposant d'unité d'épuration, et (b) taux d'eaux usées industrielles épurées, et non épurées.
Source: Boukhiar, Boutabba et Medjadj , 2022, d'après (DIM, 2020).

Plusieurs facteurs urbains influent sur l'intensité des rejets d'eaux usées dans les cours d'eau: la forte densité des populations dans les quartiers spontanés et dans le centre historique de la ville; le type du réseau d'assainissement et sa médiocrité dans les quartiers spontanés; le manque des stations d'épuration d'eaux usées et les rejets industriels dangereux.

3.3. Synthèse des liens diachroniques cours d'eau / Urbanisation

En synthèse de ce qui a précédé, les liens entre l'évolution urbaine de la ville de *Béjaïa av*ec ses cours d'eau sont résumés dans le tableau suivant (Tableau 2).

Tableau 2

Synthèse de l'évolution diachronique des liens entre la ville de *Bejaïa* et ses cours d'eaux

	Epoques: antique et médiévale	Epoque coloniale	Epoque postindépendance
Dynamique urbaine et occupation des sols	Urbain, Agricole	Urbain, Agricole	Urbain, Industrie, Trafic, Energie
Pressions sur les cours d'eau	Extraction d'eaux	Drainage, Dérivation, Pollution	Drainage, Artificialisation, Pollution, Imperméabilisation, Aménagement d'ouvrages,
Altérations structurelles et fonctionnelles	Absent	Hydrologique, Morphologique, Physico-chimique	Hydrologique, Morphologique, Physico-chimique

Source: Boukhiar, Boutabba et Medjadj, 2022.

Suite aux altérations, des actions de protection des personnes et des cours d'eau ont été mises en place. D'une part, ces actions visent à protéger les populations des risques que peut engendrer le milieu rivulaire. D'autre part, elles soulignent la protection ou la restauration des écosystèmes des cours d'eau (Tableau 3).

Tableau 3

Actions de préservation des deux composantes rivulaire et anthropique de la ville

	Epoques: antique et médiévale	Epoque coloniale	Epoque postindépendance
Actions de préservation du milieu naturel des cours d'eau	Absent	Absent	Gestion des sources de pollution (épuration des eaux usées, mesures contre les industriels pollueurs)
Actions de préservation du milieu anthropique	Absent	Préservation de la santé publique	Protection contre les crues

Source: Boukhiar, Boutabba et Medjadj, 2022.

4. CONCLUSIONS

L'objectif de ce document est de retracer l'évolution, dans le temps, des liens entre le phénomène urbain et les eaux de surface dans la ville de Bejaïa. Grace à la méthode diachronique utilisée, nous avons sillonné les caractéristiques de chaque époque, depuis la création de la ville jusqu'à nos jours.

Nous pouvons avancer qu'au cours des époques antique et médiévale, les effets des activités anthropiques susceptibles de provoquer des altérations sur les cours d'eau restaient négligeables et vice-versa.

Les conflits entre cours d'eau et extension urbaine dans la ville de *Béjaïa* remontent à l'ère de l'anthropocène. Cette époque est caractérisée par l'avènement de l'activité industrielle et par la rapidité, la spontanéité et la densification du tissu urbain. Ce dernier devient alors aussi dense qu'étalé.

Ainsi, les cours d'eau ont fait l'objet d'empiètements morphologique, hydrographique et hydrologique. Les facteurs d'altération, souvent cumulatifs dans l'espace et dans le temps, renforcent considérablement la vulnérabilité de la ville face à de nombreux aléas rivulaires, qu'ils soient naturels ou provoqués par l'Homme.

Partant de ce postulat, l'urgence est d'adapter les systèmes de gestion des différents secteurs de la ville. Les acteurs urbains doivent s'engager dans un système de gestion pluridisciplinaire (Idjeraoui, Boutabba et Mili, 2019), qui prendra en compte le fonctionnement harmonieux de la composition naturelle des cours d'eau et des formations artificielles du phénomène d'urbanisation, dans la ville de *Béjaïa*.

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