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ANALYSIS OF EVOLUTION AND MORPHOLOGY OF URBAN AND ROAD NETWORKS: CASE STUDY LEBANON-NABATIYEH AREA

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1. INTRODUCTION

For researchers, the connection between urbanization and transportation is fascinating. The management of transportation and its effects on the environment is a part of urban environmental management. Nonetheless, transportation and mobility significantly impact the quality of life and metropolitan economies. Urban planning and transportation must be coordinated to ensure sustainable urban transportation development (Cervero, 2013; Gallez et al. 2013). Urbanization is a significant trend in human history that has had a considerable impact on our environment and society. Urbanization has increased over time, and it is anticipated that this tendency will persist in the next years (Bai et al. 2017).

Urban expansion management has already proven to be problematic, and future predictions indicate that this difficulty will only increase. Since 1950, the number of people living in cities has more than doubled, reaching almost 3 billion in 2000, or about 47% of the world's population (Angel et al. 2005). Over 6.2 billion people, or about two-thirds of the world's population, are expected to live in urban areas by 2050 (Angel and Sheppard, 2005). Multiple processes influence urban development, including demographic change, particularly migration, sub-urbanization and revitalization of urban centers, decentralization of services and employment opportunities, and many others (Fedra, 2010). On the one hand, urban growth in many cities is an indicator of social, economic, and political growth; but it has negative effects on agricultural land and city greenery (Karanam and Neela, 2017). Urban expansion also causes landscape transformations and degradation through fragmentation and ecological changes (Dewan et al. 2012).

The evolution of urban and road networks can be defined as the process of changes in their spatial configuration, connectivity, and accessibility over time. May and Li (2017) investigated the spatial-temporal evolution of road networks and urban growth in Wuhan City, China, and discovered that urban growth and road network development were inextricably linked, with road network density increasing as urban expansion increased. Sun et al. (2019) used GIS and remote sensing to examine the spatiotemporal patterns of urbanization and road network evolution in Shanghai, China, and discovered that road network density increased with urban expansion. These studies highlight the importance of geographic information systems (GIS) in understanding the evolution of urban and road networks in response to urban growth, as well as the need for sustainable urban planning to mitigate negative environmental impacts. GIS can also be used to simulate future urban and road network development scenarios based on various policy and investment scenarios. This can assist planners and policymakers in making informed decisions regarding infrastructure investments and land use planning.

For a better understanding of how urban and road networks have changed throughout time, morphology and distribution patterns must be analyzed. Urban morphology is the study of how the physical and spatial elements of the urban structure, including lots, blocks, roads, buildings, and open spaces, are affected by the process of urban development (Lau, 2011). Strano et al. (2012) revealed that the homogenization of cell shapes and the stability of the roads, which form the spine of the urban structure, are characteristics of urbanization. Urban morphology can affect the quality of urban life and the pleasantness of life. Overcrowding, congestion, air pollution, and lack of green space are some of the negative attributes of urban development. Nonetheless, there is a growing emphasis on connecting urban form with sustainable city growth. Wang (2018) insisted that sustainable urban forms should prioritize compact, mixed-use development, pedestrian-friendly streets, public areas that promote social interaction, and public transportation that can help to reduce car dependence and energy consumption (Jenks and Burgess, 2017; Newman and Kenworthy, 2015).

On the other hand, the road network has rapidly expanded since the early 1900s, serving as the main infrastructure and defining characteristic of many regions (Forman and Alexander, 1998). The layout of the road network is influenced by several elements, and it necessarily changes through time and in different places. By making more land accessible, the expansion of the road network has boosted regional economic growth (Baum-Snow, 2007). From the human perspective, the road network has been the spatial structure of economic management and development, as well as population distribution. Furthermore, various variables such as typology may influence the development of the road network (Saunders et al. 2022). Streets come in a variety of shapes and sizes, and they reflect the economic, historical, and topographical conditions of cities (Ali, 2010).

Marshall (2016) contends that a well-designed road network can improve a city's livability by encouraging active transportation modes such as walking and cycling. In addition, cities with compact, well-connected road networks and public transportation systems that prioritize pedestrians and cyclists, are more sustainable than those with sprawling, car-dependent road networks (Schiller and Bruun, 2017; Brelsford and Zevenbergen, 2014). Özhan and Özhan (2016) used GIS to analyze the spatial and morphological characteristics of the road network in relation to land use patterns and found that the road network was closely linked to the distribution of different land use types, such as residential, commercial, and industrial areas.

Moreover, several studies on urban expansion and morphology show that roads are a key driver in urban evolution and one of the most important factors in the urban form (Zhao et al. 2017). The street pattern controls the morphology and orientation of buildings, where it is topologically identifiable, such as a grid pattern or a linear pattern. According to Li and Li (2015), the study of urban morphology helps with understanding a city's form and structure as well as how it has changed over time, whereas the study of urban evolution will give insight into how urban areas have developed, including changes in population, land use, and economic activity. Understanding the relationship between urban morphology and evolution is essential for urban developers, planners, and designers who want to create effective urban development and management strategies (Jiang, 2017).

Furthermore, topography influences the evolution and morphology of urban and road networks. According to Zhang et al. (2019), topography influences urban area spatial patterns because cities typically grow along flat terrain, valleys, or coastal areas. Additionally, topography affects the transportation network because the location of roads and highways has always been constrained by terrain (Wang et al. 2019). Integrating topography into urban and road network planning, as well as studying its evolution and morphology while evaluating its influence, are critical for creating sustainable and efficient urban development (Wang et al. 2018, Sagris et al. 2020).

Where the urban block is used as a tool for urban design, the street pattern is determined by the placement of the blocks. Krier (1984) and Krier (1994) indicated that the urban block is part of an urban area that may consist of a single building or a group of buildings. Similarly, Panerai et al. (2004) defined the urban block as a region that is physically connected and bounded by roadways. The evolution of the urban block was characterized by various changes: building format and type, block and street relationship, block functions, and others.

In this context, Lebanon, like the majority of third-world countries, has experienced rapid and uncontrolled urban sprawl as a result of corruption and limited planning regulations, as well as a lack of coordination between local and national governance (CDR, 2005). Urban sprawl, often known as the growth of urban areas, affects rural areas more severely than large city suburbs in Lebanon, partly because of insufficient zoning and land use planning. It is noteworthy that the liberation of a sizable chunk of southern Lebanon in 2000 facilitated development in the region's south. Lebanon has a scarcity of research on urban and road network morphology. This means that there is a knowledge gap regarding the structure and design of the country's urban and road networks. This gap in research can have significant implications for urban planning, transportation, and infrastructure development. It is essential to prioritize and invest in research and development to improve the urban and road network morphology in Lebanon.

The study's findings will improve understanding of the morphology of existing urban structures, their evolution, and the role of topography in shaping them, emphasizing the importance of integrating topography into urban and road network design as well as planning to produce sustainable and efficient urban development. First, the article analyses GIS data obtained from satellite images taken in 1994, 2005, 2013, and 2017 to track the evolution of the region's urban and road networks over time and determine whether topography influenced this evolution. Second, the study intends to investigate the structure of the morphology of urban and road networks and investigate how it relates to the influence of topography on their distribution. The study's outcomes will provide a better understanding of the morphology of the existing urban structure and emphasize the importance of using GIS and remote sensing applications to make informed spatial decisions to prevent unplanned urbanization by updating existing urban planning protocols.

The paper is organized as follows: The second section highlights the selection of the study area, the research methodology, and the data collection procedure. The third part presents and discusses the results. In conclusion, the fourth section summarizes the main findings of this study and presents the proposed topics for future research.

2. MATERIALS AND METHODS

2.1 Study area

The Lebanese Republic is located approximately about 34° N et 35° E, bordered by Syria from the north and east, and Palestine from the south, with a total surface of 10,452 km². This country is divided into nine governorates (Beyrouth, Mount Lebanon, Bekaa, North, South, Nabatiyeh, Aakkar, Baalbak El-Hermel, and Keserwan Jbeil) which are subdivided into twenty-six districts (qadaa or caza). Different districts, including the Nabatiyeh region, suffer from unplanned rapid urbanization and have experienced strong land cover dynamism (UN, 2021). In a more detailed way, the accelerated unplanned urbanization of the country, and especially in the southern part including the Nabatiyeh region and its surrounding areas, occurred mainly in the period extending between the years 2005-2013 (Verdeil et al. 2019). This particular period of accelerated and unchecked urban growth was observed as a result of various political, security, economic, and immigration events in the nation, specifically: (1) the Israeli withdrawal from the southern region of Lebanon; (2) the conflict with Israel in 2006 and the post-Lebanon-Israel war reconstruction; (3) the influx of cash deposits to Lebanese banks in 2008; and (4) the Syrian war and the immigration of Syrian refugees toward Lebanon, as noted by Al-Shaar and Bonin (2021), in addition to limited planning regulations.

The study area, depicted in Figure 1, was selected due to the rapid and unplanned urbanization in the region. The area encompasses several villages, including Kfar Remmane, Zebdine, Nabatiyeh ElTahta, Nabatiyeh ElFaouka, KfarTebnite, and Maifadoun, with the primary focus on Nabatiyeh ElTahta and Nabatiyeh ElFaouka, which together constitute the city of Nabatiyeh and serve as the central business district of the region. Given that these villages share similar physical and socio-economic characteristics with Nabatiyeh, the findings of the study are likely to be similar if these villages were also included in the study area.

The topographic form of the Nabatiyeh district is characterized by the presence of numerous hills (ranging in altitude from 270 to 1000 m).

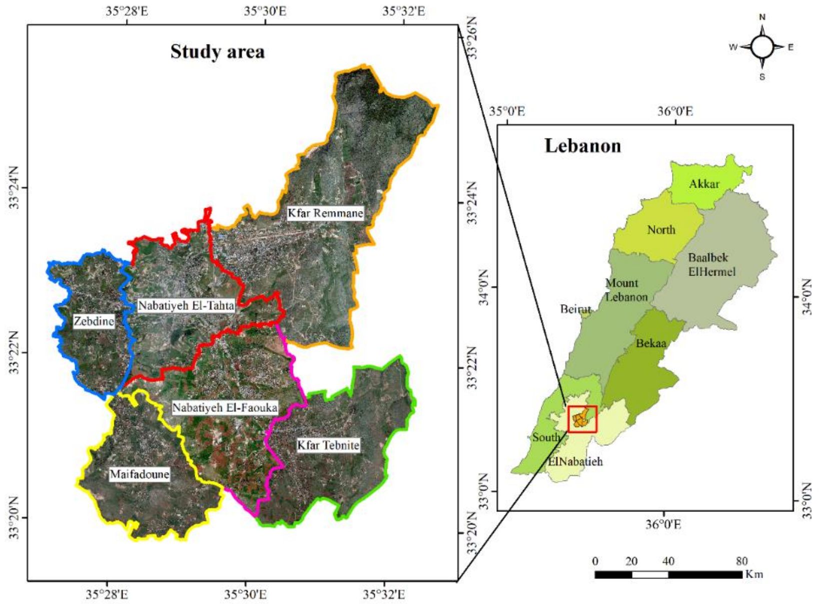


Fig.1: Study area

2.2 Data Collection

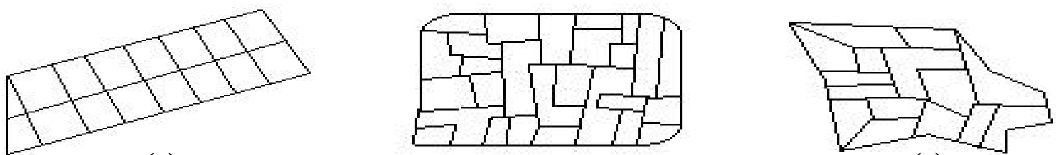
The data collection process for this study involved the collection and processing of various types of data from two different sources. In particular, the high spatial resolution satellite imagery, GeoEye 2013 and 2017, was obtained from the National Center of Remote Sensing in Lebanon (NCRS-L), with a spatial resolution of 50 cm (NCRS, 2013), which was used for supervised classification. Additionally, urban area data from 1994 and 2005 were acquired from the same source. The digital elevation model with a spatial resolution of 10 meters was obtained from the USGS Earth Explorer website (Earth explorer, 2022) and was utilized to generate the elevation and slope maps using ArcMap 10.8 software. Moreover, road network data, the vector layer, was obtained from the OpenStreetMap website (OSM, 2022).

2.3 Morphology of Urban and road networks

Many heuristic methods have been employed throughout history to sustain effective growth in urban planning, and the technique of "urban morphology" is one of these (Hazar and Kubat, 2015). Urban morphology refers to the examination of the physical layout and design of human settlements at various levels, to comprehend their spatial organization and distinctive features, as well as the mechanisms that drive their evolution (Schirmer and Axhausen, 2016).

In this phase, the way of distribution of urban buildings sites and road networks is defined in an urban block (Ravari and Mazloomi, 2015), was listed below:

a) Regular rectangle: It refers to the overall shape of building sites, which is a rectangle with a similar orientation.
b) Irregular rectangle: It refers to the overall shape of construction sites that lacks orientation when compared to a regular shape.
c) Polygon: It refers to the overall shape of building sites without any orientation and with a different polygonal form.

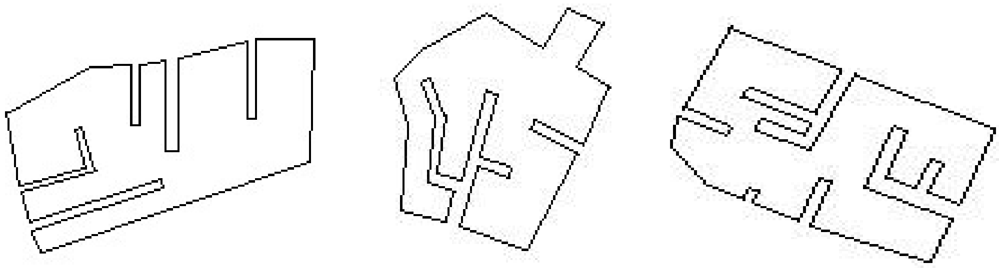


(a) (b) (c)

Fig.2. Building sites distribution: (a) regular rectangle, (b) irregular rectangle, (c) Polygonal

The road network, where paths are the primary aspects of morphology and a component of the blocks and urban form, has been divided as follows:

a) Linear distribution: This is when a path enters a block directly, has some branches, but overall maintains a straight line.
b) Tree distribution: The paths cover the entire block and are divided to the right and left. This is due to their resemblance to trees. They are known as tree distribution.
c) Network distribution: The paths are divided into blocks and are branched in parallel lines in one direction of the main path. They connect all or part of a network.



(a) (b) (c)

Fig.3. Road network distribution (a) linear, (b) tree, (c) network

In our study zone, the mentioned distribution type was indicated in each block to define the relationship between the morphology of urban and road networks.

This step entails gathering buildings of the same type that are separated by major roads at a distance of 150 meters. Satellite images with high spatial resolution were used to distinguish between condensed and uncondensed urban areas and to conclude that these areas have different types of buildings.

2.3 Methodology

2.3.1 Identification of urban and road networks morphology and Evolution

The methodology used in this study consists of several steps to investigate the morphology and evolution of urban and road networks in the Nabatiyeh region and their relationship with topography. For that, we conducted a monitoring study using GIS (Geographic Information System) to analyze satellite images and land use data for the years 1990, 2005, 2013, and 2017 to assess the studied area's evolution and urban growth. We additionally applied equation 1 to calculate the annual urban growth percentage rate (K), which is an important metric for assessing urban expansion (Xiao et al. 2014) and it is defined as follows:

$$K = \frac{(U_b - U_a)}{U_a} * \frac{1}{T} * 100\% \qquad (1)$$

where K is the annual urban growth percentage rate, Ua and Ub represent the urban area at the beginning and end of the monitoring period, respectively, and T is the period from the time a to time b.

We used the results of this formula to evaluate the spatial expansion of each urban growth rate in areas with varying slope intervals: below 5º, 5º -10º, 15º-25º, and above 25º. We were able to gain a better understanding of the distribution of urban growth across different slope intervals and how it has changed over time using this method.

Then we examined the correlation between the morphology of urban and road networks and the influence of topography on their distribution. For this purpose, the study will employ a methodological approach that includes the following steps to reach this objective: (a) supervised classification of satellite imagery; (b) definition of urban and road network distribution based on existing literature; and (c) determination of the impact of topography on their distribution.

In this scientific research, the extraction of the urban class was conducted using the Maximum Likelihood Classification (MLC) tool in the ArcMap 10.8 software, utilizing high spatial resolution GeoEye imagery with a 50 cm spatial resolution, and for the two periods 2013 and 2017. The supervised classification method enabled the analyst to generate representative parameters for each class of interest through the identification of known pixels. This is known as training, and it involves manually indicating 8 to 10 polygons for each class (urban, vegetation, road, bare soil, water, forests, and others), where a classified raster had been generated. The inclusion of more classes increases the precision of the classification result. The categorized image was filtered using the "majority filter" function in ArcMap, where the kernel size was determined by deciding how many nearby cells to include. To extract the urban shapefile from the classified image, a raster-to-vector conversion tool was applied, where for both 2013 and 2017, urban areas were extracted. And as mentioned previously, NCRS-L provided the urban areas between 1994 and 2005. Additionally, for the same periods the, road networks layer was obtained from the OpenStreetMap website.

Then, the urban block is defined as the area between the edges of two streets that are occupied by single or multiple buildings. The urban block layer was extracted from the main urban shapefile and its boundary was adjusted based on two additional criteria. The first condition involved taking into account the building type, such as a simple house, villa, multi-story building, religious structure, camp, and others. The second one, based on Schonig et al. (1999), specified that the maximum allowed distance between buildings is increased from 50 to 200 meters for a specified selection of building types, whereas in our study area, a distance of 150 meters was taken between the outer building and the nearest one in an urban block.

Following that, the changes in the urban and road networks over the period of four years were identified, with a particular emphasis on their development in different slope categories, by using the spatial join tool in ArcMap, to find the concentration zones of the urban development.

The following graph (Figure 4) presents the processes of the methodology to be performed to specify the morphology and evolution of urban and road networks.

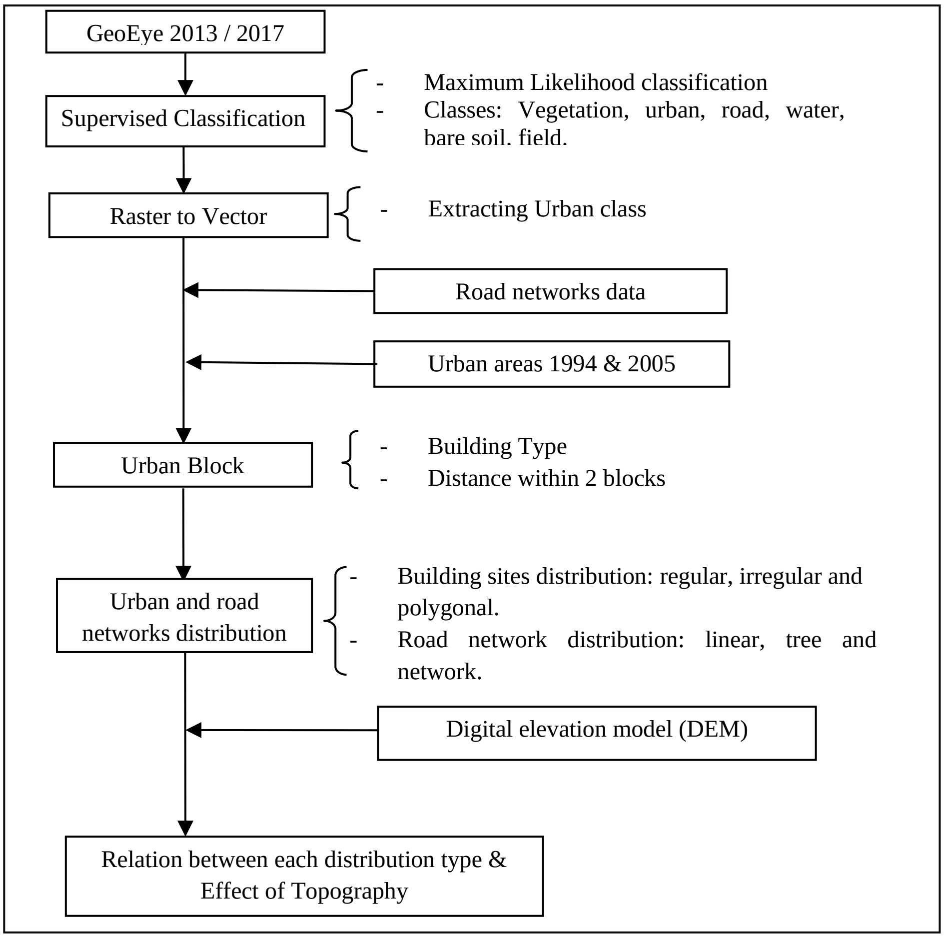
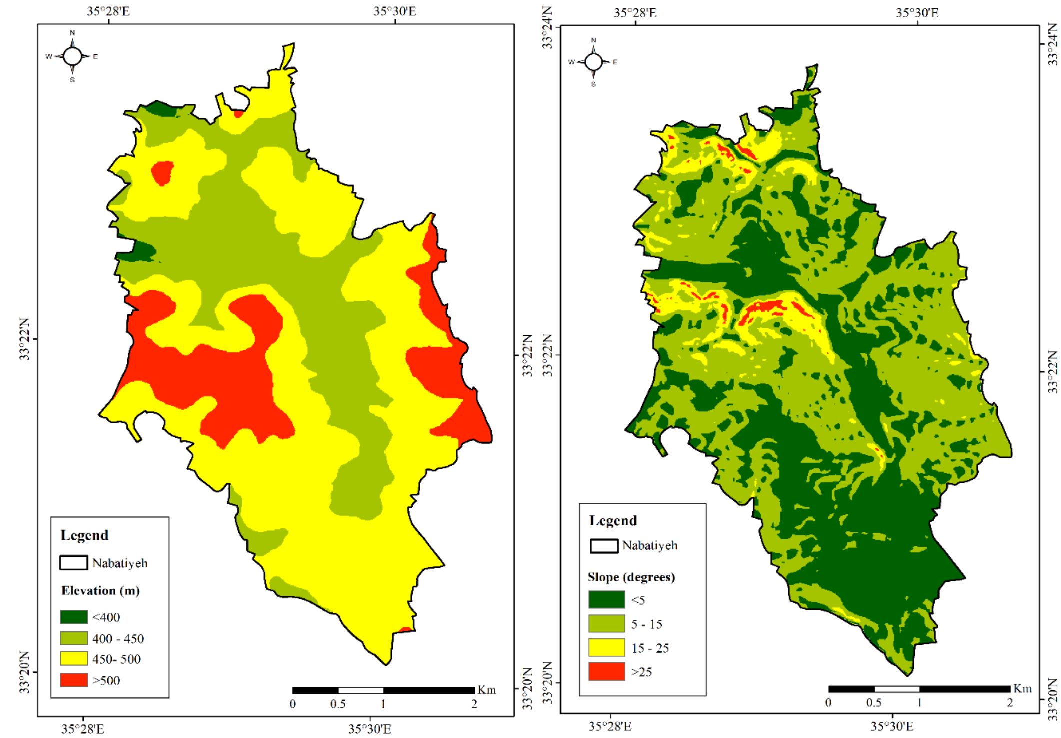


Fig.4. Flow of methodology

2.4 Topography Effect on Urban and road distribution

Our goal in this part is to investigate any possible connections between topography and the distribution of urban and road networks in rural areas. It has been proposed that topography, which is defined as the physical characteristics of a land surface, including elevation and slope, has a substantial impact on urban existence (Gao et al. 2016), where multiple research emphasizes the relationship between urban form and topography (Gharai et al. 2021; Marpu et al. 2014). As a consequence, we intend to investigate whether topography influences the evolution of urban and road networks over time, as well as morphology, which determines the distinctive urban and road distribution patterns found in villages. ArcMap 10.8 was used to create slope raster data using a Digital Elevation Model (DEM) to establish the elevation of each village, which was then split into degree-based value intervals (Figure 5).

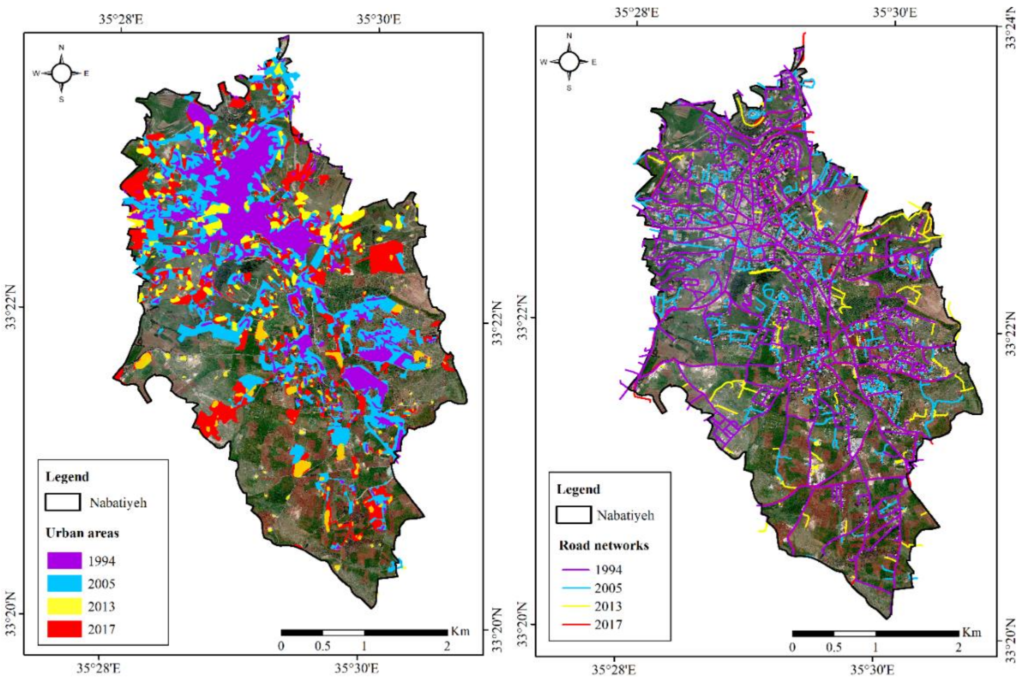


(a) (b)

Fig.5. Geo-processed layers: (a) Elevation, (b) Slope

3. RESULTS AND DISCUSSION

The spatial map in Figure 6 shows a visual display of the development of Nabatiyeh's urban areas and road networks between 1994 and 2017. Urban area changes are shown in panel (a), while the expansion of road networks is shown in panel (b), both over the same period. The results show that Nabatiyeh's urban development has significantly expanded, especially between 1994 and 2005. And the road network data, also shows a similar rise in length during the same period, reflecting this development.



(a) (b)

Fig.6. The spatial development of Nabatiyeh's (a) urban areas, (b) road networks, between 1994 and 2017.

Significant changes in urban development have occurred in the study area over time. The urban area increased from 1.97 km^2 in 1994 to 5.86 km^2 in 2017 (Table 1), showing an overall growth of 197%, according to the data presented in this table. Due to the independence of South Lebanon in 2000, the year 2005 saw the highest rate of urban expansion, with a growth rate of 12.09%. From 2005 to 2017, urban areas grew at an average yearly pace of 4.48%, steadily slowing down.

Table 1 shows the annual urban growth percentage rate (K), which is an important index for assessing urban growth and the distribution of urban areas according to the slope intervals. Figure 7 depicts the four-year urban expansion.

Table 1. Urban areas change between 1994 and 2017

Year	1994	2005	2013	2017
Urban areas (Km^2)	1.97	4.59	4.97	5.86
Annual Urban Growth (K) (%)	-	12.09	1.03	4.48
Slope (degrees)		Urban areas (Km^2)		
< 5	0.94	1.71	2.60	2.90
5 - 15	0.87	2.56	1.96	2.50
15 - 25	0.11	0.26	0.34	0.39
>25	0.05	0.06	0.07	0.07

The slope of urban areas is also provided, which is an important factor to consider when planning and developing urban infrastructure. Table 1 depicts the spread of urban areas along various slope intervals showing the distribution of urban areas based on slope categories ranging from less than 5 degrees to more than 25 degrees. The area with slopes less than 5 degrees increased from 0.94 km2 in 1994 to 2.90 km2 in 2017, while the area with slopes between 5-15 degrees increased from 0.87 km2 in 1994 to 2.50 km2 in 2017. The areas with slopes greater than 15 degrees remained relatively small, with a total area of 0.61 km2 in 2017. The majority of urban growth is shown at slopes less than 15 degrees, notably along slopes between 5 and 15.

On the other hand, from 1994 to 2017, Nabatiyeh's road network expanded as well, as seen in Table 2 and Figure 8. Road networks' overall length expanded from 120.89 km in 1994 to 138.13 km in 2017, representing a 14.29% overall growth rate. The period between 1994 and 2005 had seen the highest growth, with an evolution rate of 5.89% annually, much like the rise of urban areas. The majority of the roads in Nabatiyeh are situated on slopes with a gradient the percentage of roads with slopes of 5 to 15 degrees is made.38 % of the total road length in 2017. It is important to note that road networks and urban areas displayed comparable growth trends and dispersion at various slope intervals, showing a potential relationship between these two factors of less than 15 degrees, which accounted for 84.34% of the total road length in 2017.

This shows that new road networks were developed in the area to assist the expansion of urban areas.

Table 2. Road networks change between 1994 and 2017

Year	1994	2005	2013	2017
Road Networks Length (Km)	120.89	128.01	129.61	138.13
Evolution rate (%)	-	5.89	1.25	6.57
Slope (degrees)		Road Networks length (Km)		
< 5	50.13	50.82	51.07	53.99
5 - 15	62.14	67.96	69.31	72.36
15 - 25	6.86	7.53	7.26	9.40
>25	1.76	1.70	1.97	2.38

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The relationship between the development of the urban and road networks in the study area and how those networks relate to the terrain is clear from the table. The slopes with the highest growth rates in both urban areas and road networks were those with slopes less than 5 degrees, demonstrating a preference for development in flatter locations. Urban areas and road networks both experienced slower growth rates as the slope increased, with the highest slopes above 25 degrees experiencing the slowest growth. This shows that Nabatiyeh's topography significantly influenced the spatial patterns of the development of urban and road networks. Urbanization and the development of road networks were more easily accomplished in locations with flatter topography than in those with harsher terrain. Overall, the relationship between the evolution of the urban and road network and topography highlights the significance of taking land topography into account while planning and controlling the development of the urban and road network in Nabatiyeh.

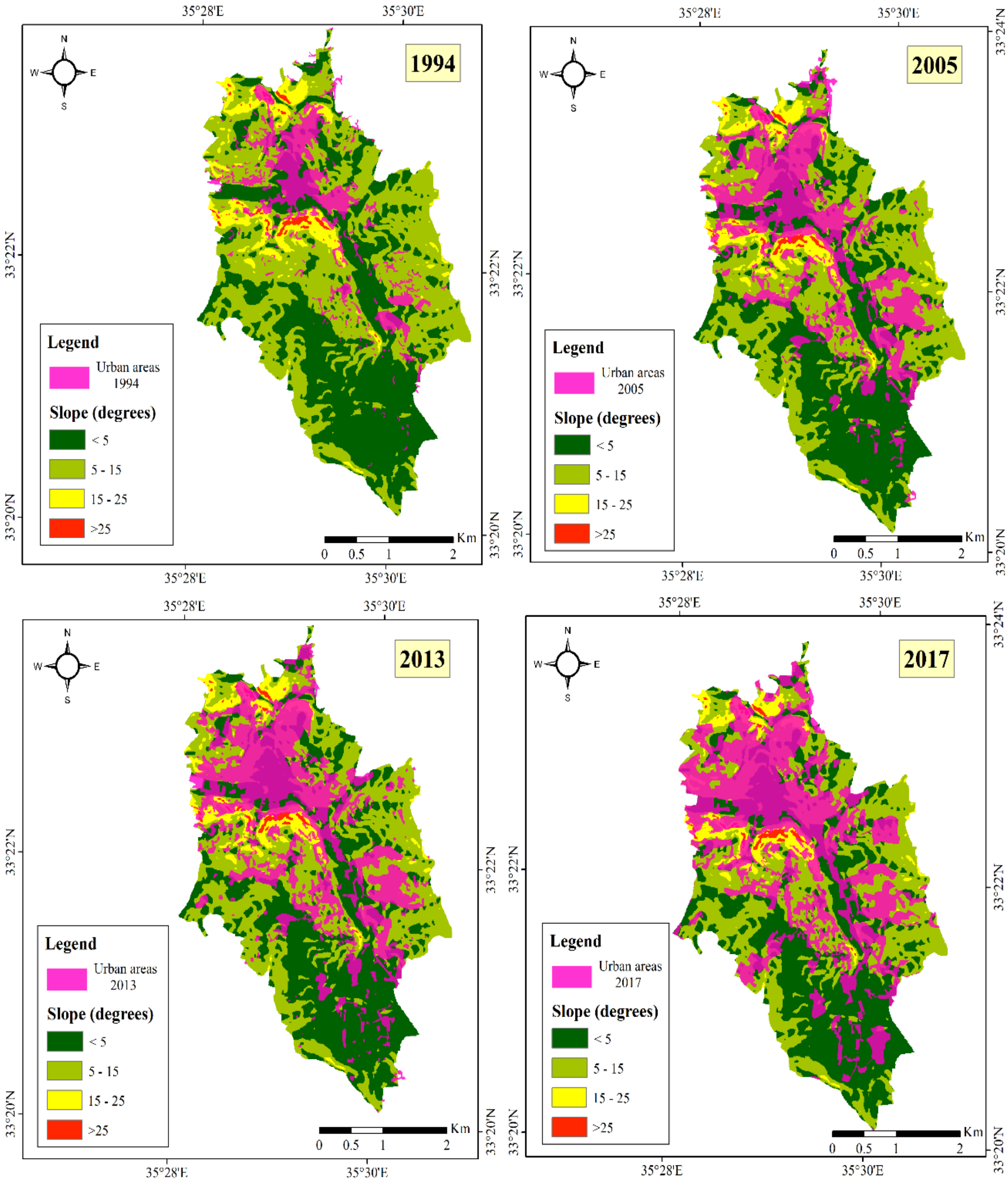

Fig.7. Urban areas distribution with respect to slope

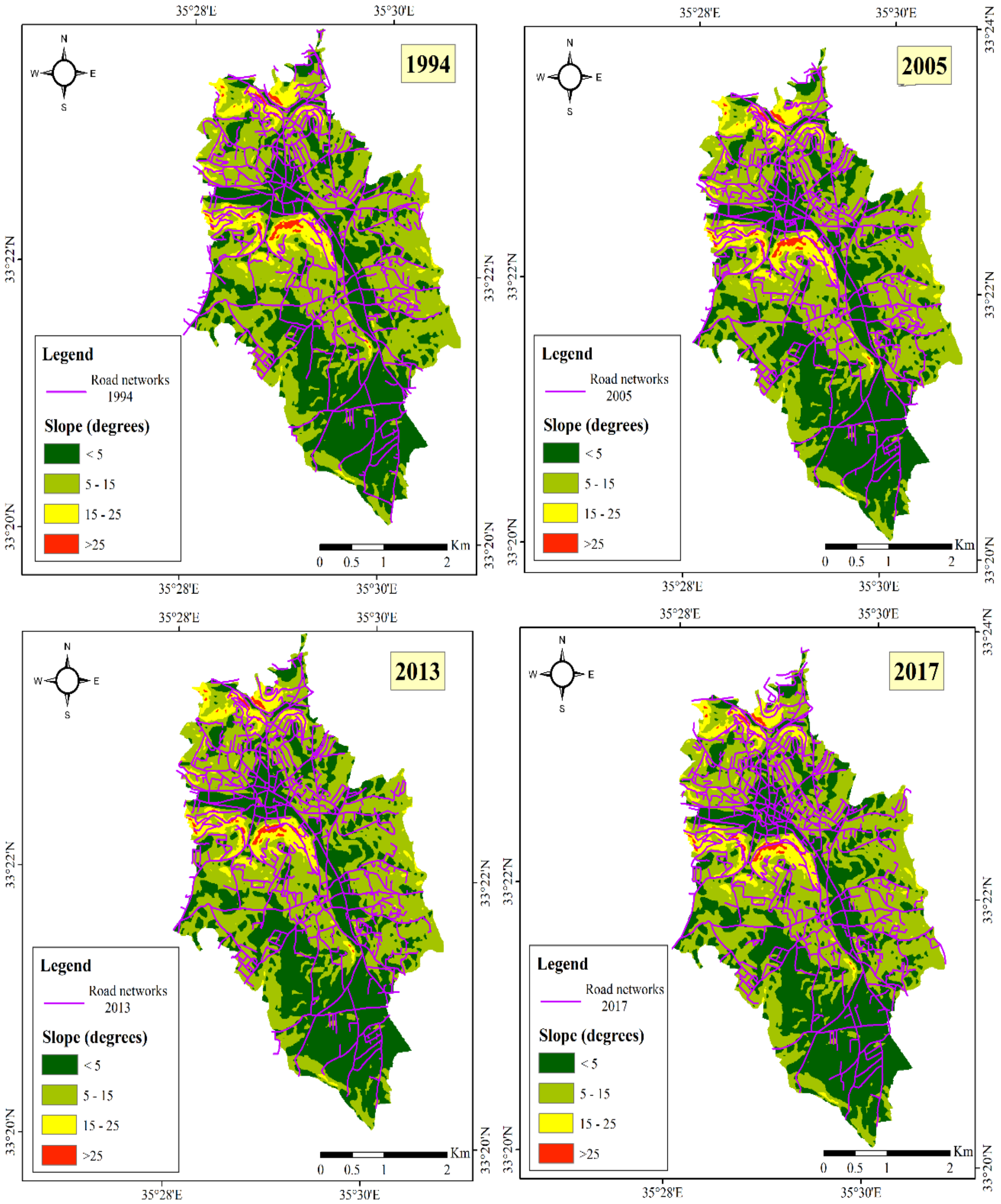

Fig.8. Road networks distribution with respect to slope

The study's findings also provided significant additional knowledge about the morphology in the study area's approach. According to the data, polygonal urban blocks in all of the villages had the highest value overall when compared to other types (Figure 9). In Kfar Remmane specifically, polygonal urban blocks made up 0.8 km^2 or 57% of the total area of urban blocks (Table 3). Similarly to this, 82% of the urban block area in Nabatiyeh ElTahta was made up of polygonal blocks. This finding implies that the great majority of the urban area in the research area was created without any orientation and clear urban planning, which may have consequences for the general functionality and livability of the urban development.

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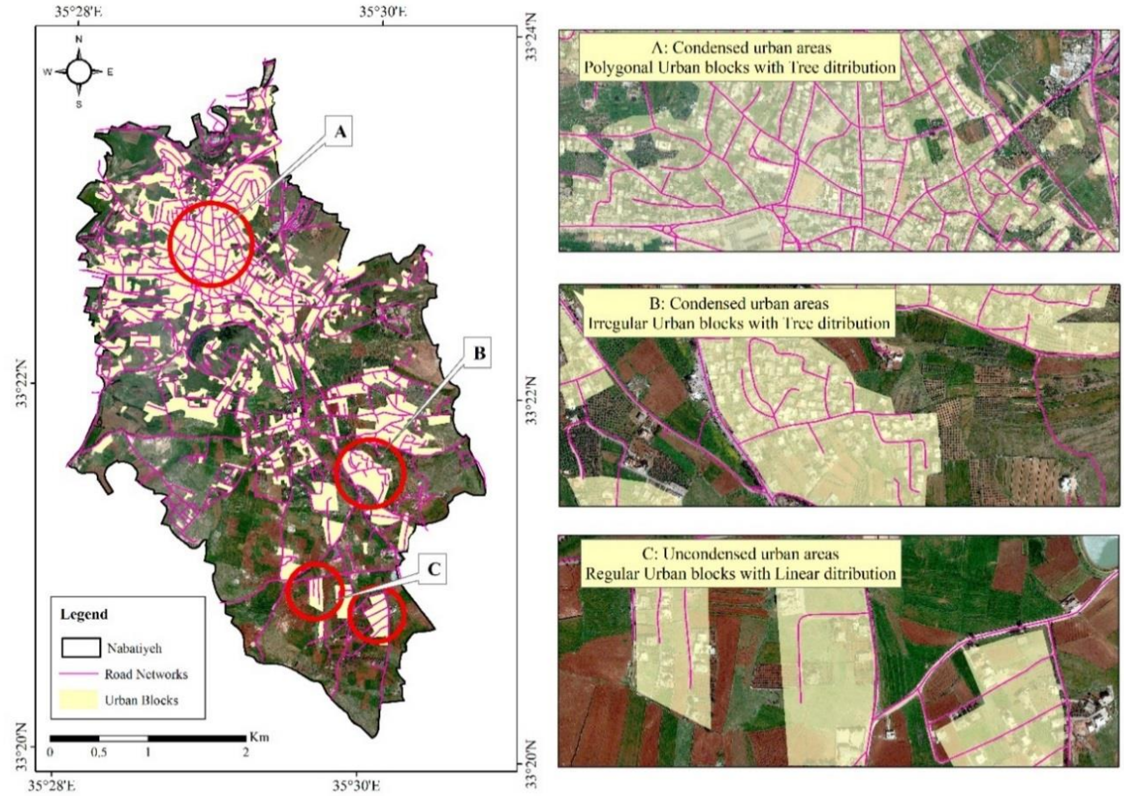

Fig. 9. Linked urban and road network distribution

The significance of regular blocks was not as crucial as the polygonal type. In Nabatiyeh ElFaouka, the regular type comprised the highest percentage of urban blocks, with a total area of 0.4 km^2, which accounted for 23% of the total urban block area. On the other hand, Kfar Tebnit and Zebdine had the lowest percentage of polygonal-type urban blocks, with an area of 0.1 km^2, which represented 10% of the total urban block area.

Irregular rectangle urban blocks were the least existing in the study area. In Nabatiyeh ElFaouka, the irregular type comprised the highest percentage of urban blocks, with a total area of 0.4 km^2, which accounted for 30% of the total urban block area. On the other hand, Nabatiyeh ElTahta had the lowest percentage of polygonal-type urban blocks, with an area of 0.1 km^2, which represented 4% of the total urban block area.

On the other hand, when looking at the type of road network, the distribution of tree-type roads is the most prevalent in all villages, accounting for the highest percentage at 85%. The linear type makes up 10% of the road network distribution, while the least common type is the linear one at only 5% (Figure 10).

The resulting areas are presented in the Table, for each type of urban block.

Table 3. Building sites distribution areas

Villages	Number of Urban Block	Total Area of Urban blocks (Km^2)	Area of Polygonal blocks (Km^2)	Area of Regular blocks (Km^2)	Area of Irregular blocks (Km^2)
Kfar Remmane	69	1.4	0.8	0.2	0.4
Kfar Tebnit	66	1	0.8	0.1	0.1
Maifadoune	61	1.1	0.8	0.2	0.1
Nabatiyeh ElTahta	43	2.8	2.3	0.4	0.1
Nabatiyeh ElFaouka	44	1.3	0.6	0.3	0.4
Zebdine	38	1	0.8	0.1	0.1

Based on our analysis and the accurate visual interpretation of the distribution patterns observed in urban and road networks, a clear relationship between these two structures was detected. Firstly, the building sites are irregular rectangles with no discernible orientation in the condensed urban areas. This suggests that factors such as available land and historical development patterns may have influenced the layout of buildings in these areas. Additionally, the road networks in these areas tend to follow a tree distribution which may be required to offer access to various areas, such as the situation in Kfar Remmane and Nabatiyeh ElTahta, where the existing percentages of these two related distributions are higher than 95%. This related distribution between the irregular rectangle and polygonal, and the tree road networks, presents challenges for urban design and pedestrian access, especially in older neighborhoods or areas with a mix of commercial and residential uses, as in our case. Where more careful planning and design may be required to ensure that they are functional and accessible to all residents (Figure 9).

On the other hand, in uncondensed urban areas, the regular rectangle building sites were more prevalent. These areas tend to have linear road network distribution, similar to the case in Zebdine where the percentage of such distribution was higher at 25%; which may reflect the need for efficient transportation routes between different areas of the village.

Furthermore, our analysis indicates that the majority of the linear road distribution occurs in new urban areas, with more regular rectangle building sites.

The least type of distribution is the network distribution, it has been challenging to establish branches in one direction of the main path. This can be attributed to the lack of regulatory measures in the construction of the village, which has resulted in a lack of uniformity and consistency in the network's layout.

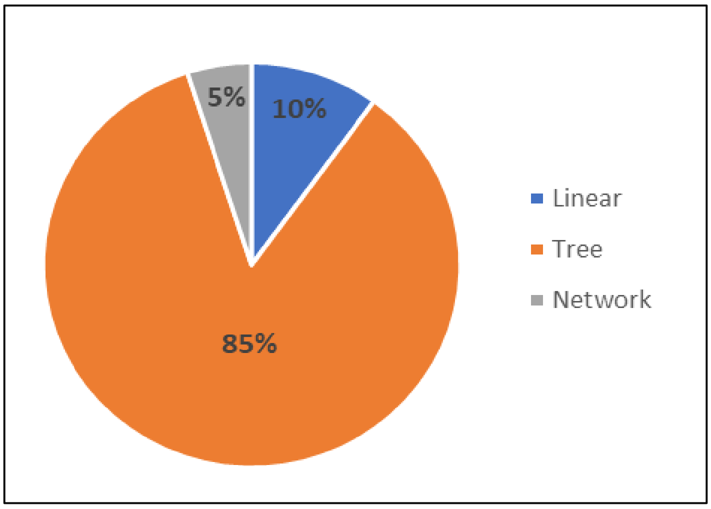

Fig.10. Pie chart showing the road network distribution

Following further investigation, our research's findings show a significant correlation between the particular distribution pattern and slope values, which represent the elevation variations. This was achieved by comparing the generated slope raster with the distribution data of building sites and routes. Our findings imply that slope variation in all studied villages is between 0º and 15º in condensed urban areas with irregular building sites and tree path distribution, specifically with elevations less than 450 m. In contrast, slope variation in uncondensed urban regions with more regular construction sites and linear path distribution ranges more than 15º, specifically more than 450 m.

These findings have significant implications for urban planning and development in these areas. To ensure efficient and sustainable use of these places while taking the environment's influence into account and preserving the area's natural topography, proper management, and planning are essential, to provide a clear open space between building sites.

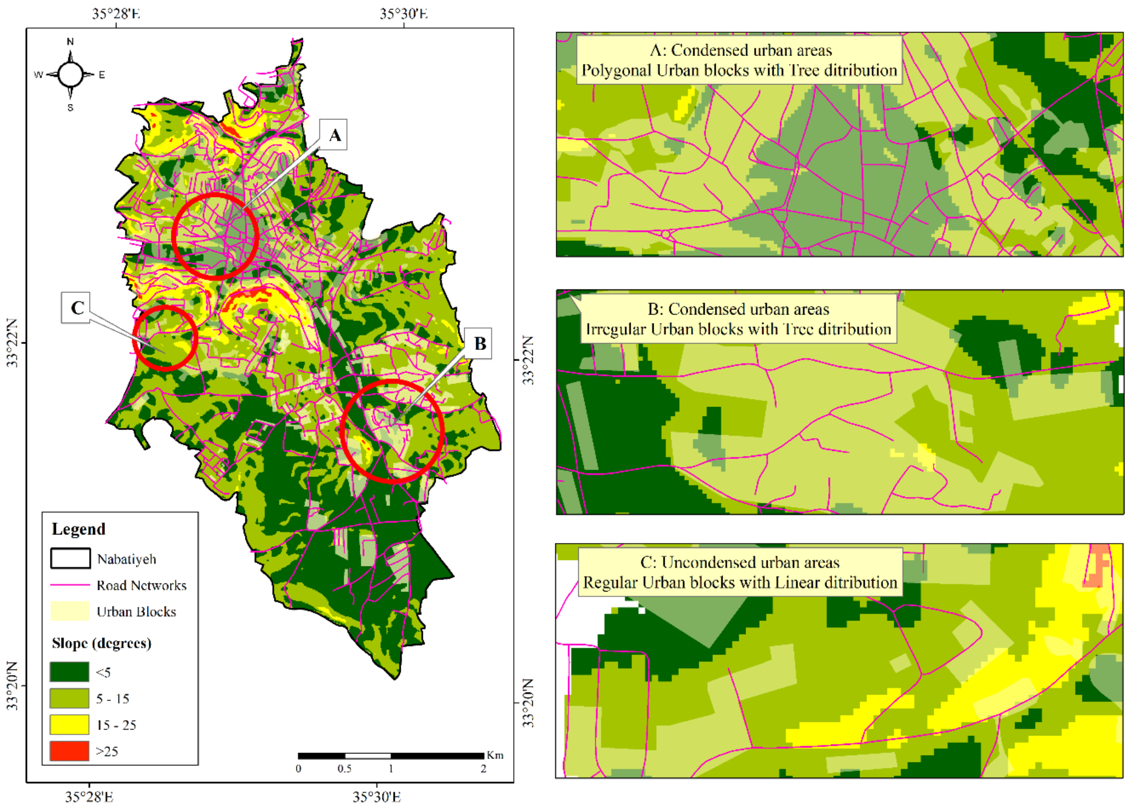

Fig.11. Linked urban and road network distribution with respect to slope variation

4. CONCLUSIONS

Urban and road networks are fundamental components of a city's morphology, shaping its physical form and influencing its social and economic characteristics. The morphology of urban and road networks can vary greatly depending on factors such as historical development, topography, and urban planning policies. Moreover, the combination of remotely sensed data and GIS was useful and efficient in assessing urban structure morphology, referring to our country's poor organization of built-up areas.

The study aims to evaluate the evolution of urban development and growth in the studied area by conducting a monitoring study using GIS and employing the formula for calculating the annual urban growth percentage rate. This method is commonly used within urban studies and offers helpful insights for urban developers, planners, and designers in creating successful approaches for urban development and management. As well as to analyze the urban and road network morphology, and their interrelationship with their different distribution patterns, and to examine the influence of topography on their distribution. In addition, it aims to gain insights into how the physical environment shapes urban and road network morphology, and how this influences urban areas' functionality and sustainability.

The study aimed to assess trends in urbanization over four years by focusing on the years 1994, 2005, 2013, and 2017. It is based on using the Maximum Likelihood classification in ArcMap, and others conversion tools, to generate the urban layer. And to obtain the necessary data for this assessment, the digital elevation model was collected from the USGS Earth Explorer website, the GeoEye satellite imagery from the National Center for Remote Sensing in Lebanon, and the road networks from the OpenStreetMap database.

The findings illustrate the clear link between the distribution of building sites and road networks in an urban block. With the effect of topography levels on the existence of the various distribution types. This study recommends that the developed urban areas should take place in areas with a slope range of 15° or more, to provide more open spaces between building sites and to improve the urban structure and infrastructure surrounding them.

This morphology exists in cities that strive for urban transportation sustainability by providing clear open space, such as Toronto which follows a network distribution of paths that lead to more regular building sites.

Overall, while irregular rectangle blocks can contribute to a diverse and interesting urban environment, they may necessitate more careful planning and design to be functional and accessible to all residents.

Understanding the evolution and morphology of urban and road networks is essential for urban planners and policymakers to design efficient and sustainable urban development. By examining the evolution, characteristics, and distribution of urban and road networks, planners can make informed decisions about transportation infrastructure, land use zoning, and urban design.

Future research should supplement the method used in this study, which tracked the evolution and morphology of urban and road networks, with the creation of a land suitability map using GIS and remote sensing technology. This additional step can improve current urban planning protocols, resulting in more sustainable and livable communities for future urban development.

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