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RESEARCH ARTICLE

# Determining the Urban Morphology of Historical Settlements through Water Supply Lines: The Case of Eğrikapı Neighborhood*

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**ABSTRACT**

The study aims to provide a new perspective toward urban morphology and archaeological research regarding determining the historical settlement areas within the framework of urban planning theories. The study reveals the spatial change in historical settlement areas over the centuries based on numerical data such as distribution plan, flow rate, construction date, and elevation values of water supply lines. The study uses the comparative analysis method for the case of the Eğrikapı Neighborhood in Istanbul, one of the neighborhoods fed by Kırkçeşme water supply lines in Istanbul between the 16th-19th centuries. In order to determine the periodical urban development of the neighborhood and the changes in the urban texture within the boundaries of the settlement area, used water supply lines. The results show that a new method, obtained through water supply lines, can be used when analyzing urban morphologies for historical settlements . This study explains the concept of habitable areas and the factors associated with them, outlining the principles for determining habitable areas based on each factor.

**Keywords:** Water supply lines, urban morphology, Kırkçeşme water supply lines

## 1. Introduction

Urban morphology generally covers the urban patterns formed by the combination of streets, parcels and buildings, which are the basic physical components of a city. The aim of urban morphological research can be expressed as explaining the essence of the forms that produce the built environment and the processes that enable the transformation of space. Urban morphology aims to explain how the components that make up an urban pattern have been formed, how they transform, and how they relate to one another (Ünlü, 2018, pp. 61–62). When looking at the historical neighborhoods of Istanbul, no clear information is generally found apart a few important neighborhoods about the urban development process of these settlements, which are the building blocks of the city. The process of urban development means that changes in the urban pattern throughout history, such as the character of the construction network (e.g., dense, sparse, wooden, masonry), the polar effect created by focal points such as places of worship and baths, and the contribution of public buildings to population movements. Fountains are one of the main factors forming the backbone of the urban system, and if they triggered the growth of cities, the fact that the spatial formation of cities throughout history revolve around fountains and distribution networks is an expected result. Ulaş and Kısa Ovalı (2017, p. 393) stated, "The characteristic features of urban growth, such as construction and road networks, can be described as cells that spread as a mass." From this point of view, one can say that extending the distribution network will cause existing land use will change and an unplanned network of parceling to emerge.

However, revealing this process with numerical data is an important process, and determining the variables in the historical process and obtain and converting numerical data into visual data are necessary (Ulas, 2021). In this regard, the following two questions are being asked: How can this developmental process throughout the history of the neighborhoods in Istanbul be determined, and what would be the most appropriate method for observation, measurement, and calculation?

Throughout historical periods, water supply lines have been an indispensable part of urban pattern and a very important urban actor. Maintaining a city's activities during its urban development involves water systems. However, more than one variable should

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be examined in this regard. The research area should be kept broad, and the study should be supported by both written and visual sources. Very little research is found in which quantitative data such as the routes for the water reaching a city, the spread of urban distribution lines, the amount of water supplied from fountains, and land use have been presented alongside urbanization. Because water is a vital necessity, how it has affected urbanization throughout history and whether it actually has an impact are important issues that need to be investigated. The changes that Istanbul has undergone throughout its history can be determined along this axis through observation, measurement, and various mapping methods. From this point of view, the aim of the study is to determine the urban development of residential areas based on numerical data regarding fountains (e.g., water distribution plan, flow rate, construction date, and elevation values) using a mapping-based method (Ulas, 2021).

## 2. Methodology

The study compares within its scope the construction techniques used in water supply lines through the Kırkçeşme water supply lines, which are understood to have the most data collected among the historical water supply lines of Istanbul, to the phenomenon of urbanization developing along the axis of the water distribution network and investigates how these interaction together. (For the first time, the hydraulic values of fountains and mapping methods are used to analyze the process of urban development of a city along the axis of water resources. The study can use the obtained results to determine where the population has been concentrated, how public and commercial buildings have been located, and what changes they have undergone over time. Finally, the study will arrange the results obtained from the analyses of other historical water systems and settlement areas that developed in parallel with these water systems under the sciences of hydraulics, urbanism and cartography and present a novel combined study.

Turoğlu and Bayraktar (2013) examined the water supply lines built in Sinop during the Roman period, as well as the dykes, pools, arches, covered water reserve structures (*maksem*), and fountains connected to these lines. Aksoy's (2015) doctoral dissertation on the Izmit water supply lines took the coordinates of the water structures for the purpose of identifying and recording as a method and arrived at significant data as a result of drawings, measurements, photography, and source scanning. By means of these data, Aksoy conducted a hydraulic analysis of the water supply line and determined the urban pattern of the city that formed around it. Margeta et al. (2018) conducted a hydraulic analysis of an idle Roman water supply line extending to the city of Solin and Diocletian's Palace and identified the topographical and structural features of the water supply line. In addition, they revealed the main transmission plan of the waterway, as well as the plan of the distribution lines.

Kafesçioğlu (2016) examined the changes in the urban morphology in the section between Karaköy and Tophane and investigated the building types and usage patterns in the urban fabric of the region. He analyzed maps of Galata, Pera, and Pangaltı that had been prepared by the Municipal Engineer G. D'Ostoya between 1858-1860, the Huber maps dated between 1887-1891, the insurance maps made by Charles E. Goad's company between 1904-1906, the maps made by Suat Nirven between 1948-1950, and lastly the current plans from 2010 in order to understand the spatial transformation. The examinations involved boundaries, building islands, building parcels, and road routes.

When considering the measurement and mapping methods used in the above studies together as a method, the research has selected within its scope the comparative analysis method, which is one of the research methods used for collecting information by examining the similarities and differences of two or more situations, events, or objects. In accordance with this methodology, the study carried out an identification analysis over the selected water supply lines and then obtained period maps showing the changes in the city's construction and road networks during the time period the water facility was in operation. The changes in the distribution plan and urban morphology were then incorporated into the current city plan. The study then compares the development of the waterway and the urban growth movement over the centuries through the integrated map obtained at the end of these processes (Figure 1).

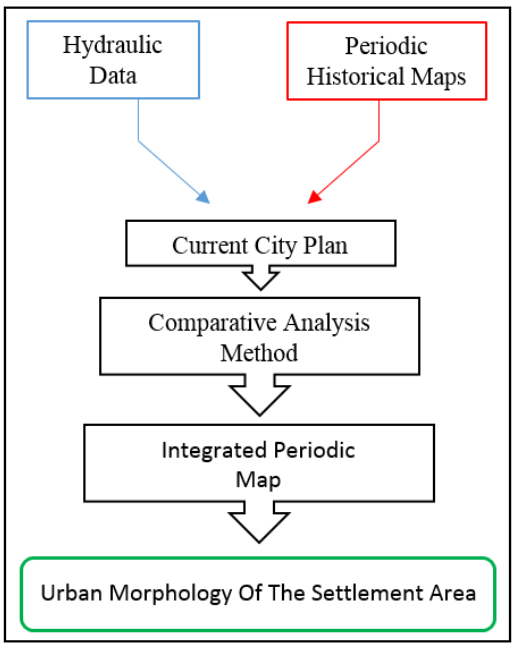


**Figure 1.** Flow diagram showing the application of the method (Ulas,2024).

## 3. Comparative Analysis of the Waterway Distribution Plan and Periodic City Maps Through the Example of Eğrikapı Neighborhood

In line with the determined method and sampling, the study first researched historical source publications before identifying the network plan for the water supply lines in the field. After obtaining the data on the water supply lines, period city plans were accessed from the maps of Istanbul throughout history.

### 3.1. Identifying the Water Network and Obtaining Information on the Fountains

Mimar Sinan's involvement in various restoration, water supply, urban development projects and the construction of different buildings in various parts of the city throughout Istanbul had provided him with experience in the city's urban morphology (Bozdogan et al., 2006). The Kırkçeşme water supply lines had been built in 1563 under the hand of Mimar Sinan; 300 fountains were built in the first phase, with new fountains being added to the main transmission line in the following years until the number reached 580 (Çeçen, 1988, p. 149). Within this scope, the research has selected as examples the Kırkçeşme water supply lines due to having the most available data, and Eğrikapı Neighborhood due to being one of the historical neighborhoods in Istanbul first fed by the facility. Information on the water distribution plan and its related structures were examined in the following sources: Prof. Dr. Kazım Çeçen (1988), Mimar Sinan's distribution notebook, the Istanbul Water and Sewage Administration (ISKI) Foundation Water Directorate, İbrahim Hilmi Tanışık's (1943) books, Affan Egemen's (1993) descriptions of the fountains, and Ayverdi's (1958), Pervititch's (1922), and Kauffer's (1807) Istanbul Maps, as well as other sources such as blog pages on the Internet describing historical buildings and oral accounts of individuals and institutions (Ulaş, 2021).

Çeçen's (1988) work identified the water network and noted the fountains on the current city plan of that day. In addition, the daily amount of water flowing from the fountains was divided into regional service branches. However, the rapid growth of Istanbul has required confirming these distribution plans on the current city map. For this reason, this article first compared the distribution plans showing the fountains on various web pages (Istanbulium, 2024) and Çeçen's (1988) plans to the current city map. The article then processed the data obtained from various sources and the distribution plans Çeçen presented over the current city plan on a tablet computer before starting the survey work in the field with topographic devices. The field study then made coordinate measurements with a GPRS device for the distribution lines, *maksems*, and fountains.

As seen in Figure 2, elevation measurements were made for the distribution lines and tap levels of the fountains; the distribution plans Çeçen (1988) drew were then overlapped with the points for which measurements were able to be made by taking into account the historical maps. The obtained data were digitally processed into a 1:1000 city plan in the AutoCAD program. While markings and drawings were made on the current plans, the daily water amounts given from the fountains were found by analyzing the flow values Çeçen presented on a neighborhood basis. For the convenience of future historical research, the flow rates of the

fountains have been calculated separately for Ottoman and modern measurement systems and shown on the map presented in Figure 3 (Ulas,2024).

**Figure 2.** An example measurement process (Ulaş, 2021).


**Figure 3.** Eğrikapı Neighborhood distribution network and fountains (flow rate, construction date, elevation value) on the city plan (Ulaş,2021).

### 3.2. Access to Maps Showing the City Plan between the 16th-19th Centuries.

With the construction of the Kırkçeşme water supply lines in the 16th century, Istanbul started to grow and develop. The Kırkçeşme water supply lines in particular were used to revive the city neighborhoods that had started to shrink after the supply of water to the fountains that had been built in previous periods had become idle (Çeçen, 1988). However, because this revitalization and growth is not evidenced with numerical data, the exact extent is unknown. For this reason, a need can be said to exist for examining the changes by showing the maps that specify the construction and road network of the city before and after the construction of the facility, as well as the plans that have information about the distribution lines.

Buondelmonti (1420) is known to have drawn the first map of Istanbul in the form of a perspective plan by making on-site observations. This map reflects the Byzantine period of Istanbul in general terms and was reprinted with varios techniques in the following centuries. The 16th-century map of Istanbul in Sebastian Münster's atlas *Cosmographia* published in Basel in 1544 is important because it was published just before the construction of the Kırkçeşme water supply lines (Yetişkin Kubilay, 2016). The map presented by Sebastian Münster in 1544 was reprinted by the German publisher and editor George Braun and Franz Hogenberg in 1572 as "Byzantium Constantinopolis" in a more detailed realistic manner. In this regard, Cahit Kayra's "Istanbul Maps" and "Maps of Old Istanbul" were the first publications to bring together different maps about Istanbul. However, instead of dealing with all aspects of maps about Istanbul, these publications were simply a compilation of the archival materials available to the author. The work *Istanbul Maps 1422-1922*, edited by Ayşe Yetişkin Kubilay and published by Denizler Kitabevi, is very important in terms of presenting a holistic cartographic history of Istanbul for the first time (as cited in Cantemir, 2010, pp. 747–750). The first scientific scale plan of Istanbul was drawn in 1786 by François Kauffer, a topographer and cartographer, 360 years after Buondelmonti had drawn the first map of the city. The 1786 map has an original scale of 1:17,280 and contains very valuable information in terms of social and architectural identification such as land and sea routes; piers and harbors; gates on the city walls; tombs and cemeteries of all religions; religious buildings including mosques and churches; civil buildings such as fountains, *ayazsma* [springs considered holy to Greek Orthodox], schools, and palaces, gardens, embassy palaces, and locations where people of all religions lived (Kaya, 2024). The 19th-century fires, especially those in the inner-city walls, caused major changes to the main spine of the city.

In this regard, Ekrem Hakkı Ayverdi prepared 1:2,000 scale maps of high scientific quality called "19th-Century Istanbul Maps", and these maps have a very important place among historical maps in terms of the determinations and detailed analysis. These provide a detailed map of streets, orchards, places of worship, fountains, and similar administrative, military, and civilian structures. In the late 19th-century, fire insurance maps had started being made in line with the needs of the foreign companies that came to Türkiye for trade purposes. These were drawn by C. Goad in 1905 and 1906 and by J. Pervititch in the 1920s. Goad Maps are quite similar to Pervititch Maps. However, while Pervititch Maps are more specific, sometimes structures that cannot be found here can be found on Goad Maps. Pervititch Maps have a higher resolution compared to Ayverdi Maps, and because they show buildings and their construction methods, they also help identify the building stock on a historical basis. The map's legend also shows the different colors for each type of building construction (Figure 4).

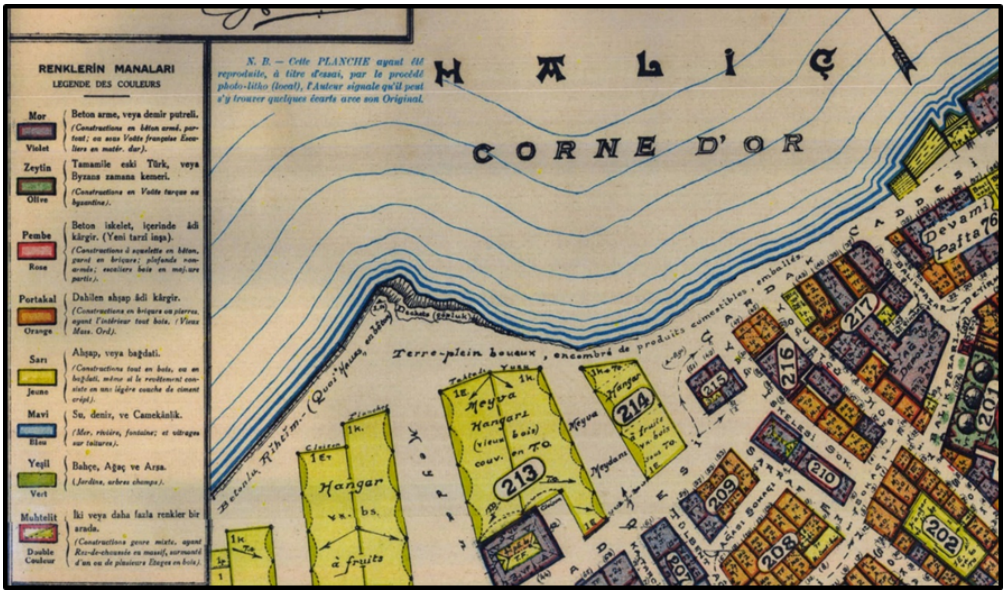


**Figure 4.** Pervititch Map (1922-1945) Eminönü sheet - A sample view showing the building stock legend (Pervititch, 1922/45, Sheet 78).

The historical maps drawn between the 16th-19th centuries enable access to most of the construction, road networks, and other urban components of those periods. Thus, the data belonging to the periodical maps alongside the data from the water distribution plan can be shown on the current city plan in different colors over the centuries. The study accessed these maps from the Fatih Municipality website, which presents them in high resolution and in layers (Fatih Municipality, 2024).

### 3.3. Showing the Water Distribution Lines on the Current City Plan Through the 16th-19th-Century Period Maps

Sefer and Ahunbay's (2015, p.78–122) study identified mosques, baths, inns, fountains, schools, and similar buildings in the neighborhoods they studied on old maps and then incorporated them into the current Istanbul plan. They were thus able to reach many important conclusions about the building stock of the neighborhoods throughout the city's history, as well as the formation of spaces and the growth of the settlement area. The current research has determined within its scope the morphology of the neighborhood and the surrounding part of the city to reveal the urban space. Based on this study method, important historical buildings have been identified within the borders of Eğrikapı Neighborhood by taking into account their construction dates. The study also examines the reconstruction activities of the neighborhood after disasters such as earthquakes and fires and found estimated construction dates for the madrasahs, baths, tombs, and houses that had been built. For this purpose, the study benefitted from written or anonymous sources describing the neighborhood along the axis of historical buildings. By taking the topography into account, the study divides Eğrikapı Neighborhood into regions before conducting the examination over the 300-year period starting in 1550 and ending in 1850 (Figure 5).

#### *3.3.1. Region A*

The part of this region starting with the *Savaklar Maksem* coincides with the starting fountain of the transmission line and is generally shown as idle areas on historical maps. Although the area around the church appears empty on the G. Braun and F. Hogenberg map, the Pervititch maps show some wooden structures thought to date back to the 16th century (Yetişkin Kubilay, 2010, p. 43–44; Pervititch, 2000, p. 29). The aforementioned Panaiya Suda Church had been built before the 9th century, and the settlement area has grown with new additions over time (Turan, 2021). Accordingly, to scan the surrounding structures of this section where the Panaiya Suda Church is located by taking into account the construction date of the church would be correct. The section seen from the hill toward the coast has a fountain that had been built between 1750-1850. However, based on the Pervitich maps, the construction can more likely be said to coincide with the period between 1650-1750, as some wooden and masonry structures are found that were built after the fire (Figure 5).

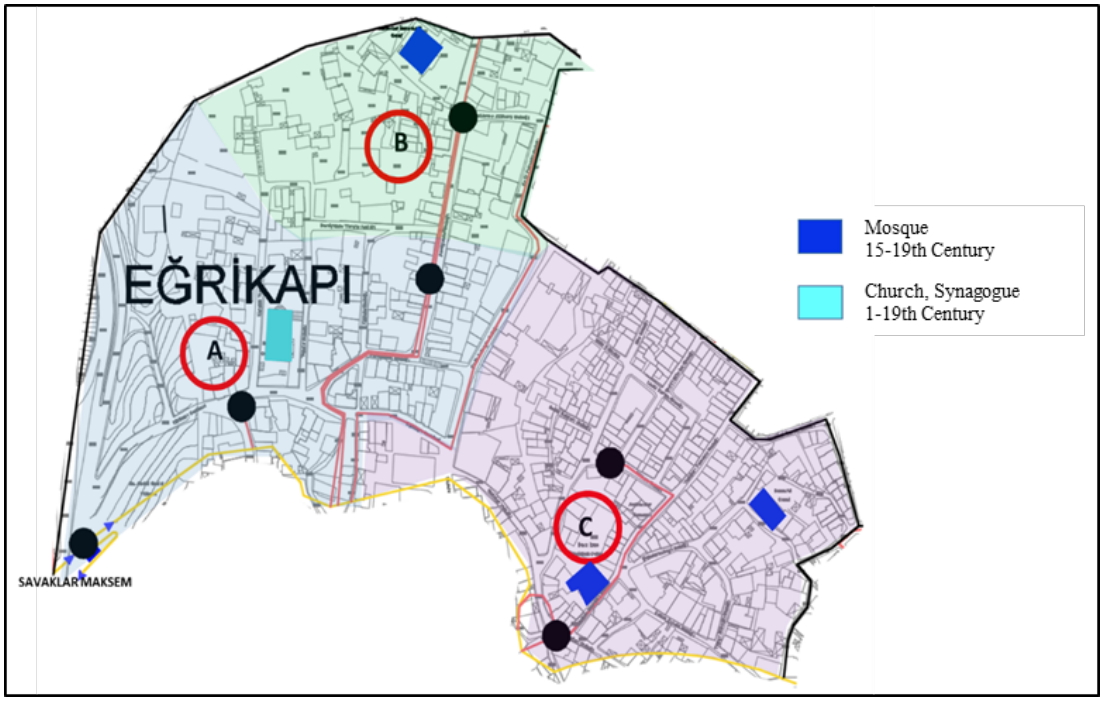


**Figure 5.** Examination of urban components by dividing Eğrikapı Neighborhood into regions in the historical process.

### *3.3.2. Region B*

One of the first period (1550-1650) fountains stands out in this part near the coast. In addition, just below the fountain is the Ivaz Efendi Mosque (1586), which had been built on the foundational remains from the Byzantine period (Üstündağ et al., 2017, p. 318). When examined from the Pervititch plans, the old-style wooden structures stand out. In addition, the G. Braun and F. Hogenberg map shows a dense construction at the base of the city wall. The study tries to determine the construction network and urbanization movement of the region by scanning the buildings with colors according to the historical period in which they were built in light of the information obtained from both the maps and source publications.

### *3.3.3. Region C*

The Pervititch and Ayverdi maps show some old-style wooden buildings in this region. In addition, old dated accounts indicate that this island was an active residential area with the Yatağan Bath (1650) and had been built in the mid-17$^{th}$ century right next to it. Also, many buildings were rebuilt after fires (Arabacılar Bath, 2024). The Hacı İlyas Yatağan Mosque and Hoca Ali Mosque (16$^{th}$ century), which served as a masjid and later a mosque especially during the reign of Fatih Sultan Mehmet, are on the periphery of the region (Üstündağ et al., 2017, p. 232). When considering the building network presented on the Pervititch sheets and the information obtained from other historical buildings, scanning the surrounding buildings as mostly early period works would be correct. However, newer construction sites are found toward the coast. By making use of historical buildings and other source publications, the scanning process was also carried out along this route as the middle period (1750-1850; Pervititch, 2000, p. 29).

After the zoning process, the buildings, fountains, and distribution lines were registered on the current city plan with the color scanning method. This updated map using the color scanning method shows distribution lines, fountains, and structures in color according to the construction date. Taking into account construction dates, the map also shows the fountains in the form of colored circles whose sizes are proportional to their flow rates and colors match their time period. The base unit of water given daily by a fountain is1 *masura* / day, namely 6.5 tons / day, and the base circle diameter has been accepted as R = 2 units, with the other circles being drawn as multiples of it according to the flow rate value. After this process, the estimated historical settlement and road network of the area in question was identified within the borders of Eğrikapı Neighborhood. The next process created a city map integrated with the water distribution lines by scanning the areas where historical buildings coincide with the current city plan (Figure 6).

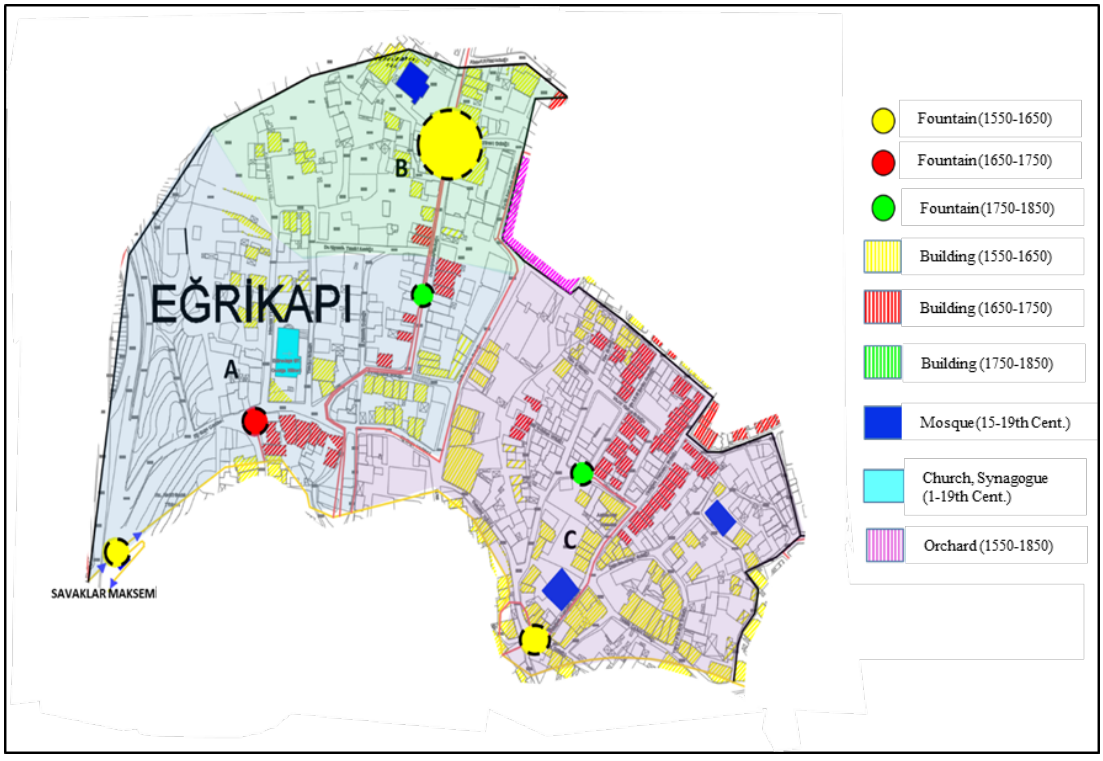


**Figure 6.** Periodic map obtained by the colorization and scanning method.

## 4. Assessment and Conclusion

This study has been conducted for the Eğrikapı Neighborhood using the comparative analysis method and observed the settlement areas to have grown and developed with the spread of the water distribution lines and the emergence of fountains. Settlement areas are understood to have been formed over time around the fountains in particular. Accordingly, the results this study has obtained can summarily be listed as follows:

When monitoring the movements of the fountains, settlement, and road network of the land over the centuries through the Integrated Periodic Map, these urban components have been determined to follow the same kind of movement and orientation, whether in unison or consecutively within a certain time interval.

The number of fountains and the area served increased as the water flow increased, some irregular growth in the boundaries of the neighborhoods was also noticed to have occurred.

Wherever the topography is suitable, fountains and places of worship move in unison.

While the urbanization movement did occur from the center to the periphery in the early periods when the water supply lines were first put into service, after the mid-18$^{th}$ century, an opposite movement from the periphery to the center was understood to have occurred.

When analyzing the fountains' elevation values; the settlement areas is understood to have moved toward the hills.

Based on the Eğrikapı Neighborhood, the ability to monitor the spatial changes that cities have undergone throughout history and to determine the construction and road network have been proven possible with the help of historical water distribution systems.

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