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Original Article

GIS-based Spatial Analysis of the Evolution of Residential Developments; A Case-study of Sulaimani city, Iraq

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Abstract: This research is aimed at visualizing the historical evolution of residential land use development of Sulaimani city based on GIS spatial analysis with the input of all of the relevant available data in various formats in order to determine the form of the city according to morphological classifications discussed in the literature of urban planning. Essentially, following the collection of data, processing, review of relevant literature and applied methods, this study draws a timeline for the spatial evolution of the city of Sulaimani in addition to constricting a spatial grid for morphological comparison of different growth stages and analysis on multiple aspects. Moreover, a number of criteria were established to evaluate spatial patterns based on published theories in the field of land use urban planning. These indicators were formulated in a questionnaire survey and determined the main aspects of the city through visualizing the process of historical evolution up to modern date. The study presents transformations and addresses current issues, as well as recommended a number of possible solutions for residential land use development in the city of Sulaimani.

1. Introduction

Cities are dynamic entities that evolve over time, shaped by a multitude of factors such as historical influences, cultural dynamics, economic forces, and spatial planning. A morphological study of a city provides valuable insights into its physical structure, urban form, and development patterns [1]. By analyzing the morphology of a city, researchers, urban planners, and policymakers can better understand its spatial organization, land use patterns, transportation networks, and socioeconomic characteristics [2].

In the context of cities, morphology refers to the physical structure and form of urban areas. It encompasses the spatial arrangement of buildings, streets, open spaces, and other urban elements. The study of morphology aims to decipher the underlying patterns, relationships, and processes that shape the urban environment [1]. It seeks to identify the factors that influence urban forms, such as historical developments, topography, infrastructure, and human activities.

Morphological studies provide valuable insights for urban designers and architects. By understanding the underlying patterns and spatial relationships, they can create more contextually sensitive

designs that harmonize with the existing urban fabric. It helps in preserving the unique identity and character of a city while accommodating new development.

2. Problem Statement

This research draws on the gap in previous literature and case studies remarking on the absence of an effective and functioning land use development plan for the city, hence this work is dedicated to overviewing and simulating the historical spatial evolution of Sulaimani city as well as its future residential urban land use development in order to propose alternative solutions for the housing issues addressed. To provide input for the application of GIS technology as a planning support tool in the process of decision-making in planning for residential land use development of Sulaimani city.

3. Research Objectives

While this study is a contribution to the process of urban planning through the provision of a better understanding of the situation, this aim can be achieved following the completion of a number of smaller goals including two basic goals covered in this paper, which is listed below:

- To study the morphological pattern of Sulaimani city and model its residential spatial evolution.
- To identify the changes and issues of designated plans in comparison with the existing situation.

4. Related Works

Originally, the term originates from "morphe", denoting form, and "logie", meaning logic, which indicates the logic of understanding the form. Originally, the ideation begun with the established concepts of Vitrivius; Utilitas (usability), Firmitas (durability) and Venustas (beauty) are disclosed by form [3]. Urban morphology is the systematic study that concentrates on the tangible effects generated by social and economic tensions and evaluates the process of in which the form and outline of cities are created. Considering the artificial fabric of cities as an outcome of the evolution of key elements shaping urban form including built structures, streets, open cpaces and their outlines facing constant alterations [4]. The studies of urban morphology has been categorized them into three main schools of British, Italian and French. Several fields of knowledge have been combined in the studies of different cities including architecture, geography and urban design, with the purpose aimed at finding the required pattern for urban morphologic study [4].

Table 1: The schools of urban morphology: foundations.

English	French	Italian
Urban form studies include descriptive and explanatory purposes on the development of the urban structure theory. Question: how the city was built and why? Conzen and Whitehand	Urban form studies include descriptive purposes on the development of urban design theory. Question: How cities should be built? Muratori, Caniggia and Rossi	Urban form studies include objective assessment of the impact of past structures in urban design theory Question: How should the city be built and the fact that when it was built? Henri Lefebvre, Panerai, Castex, to Depaul

Essentially the Classics include a normative approach taken by researchers as researchers study a specific spatial case based on the individual capacity of visual perception, in such a way that the town is approached as an object of perception of its inhabitants [5]. Novel studies regarding urban morphology in the field of geography are demonstrated in table 2, as follows: [3].

Table 2: the foundations of urban morphology.

Year	Author	Conclusions
1899	Schluter	The morphology: cultural research as a cultural landscape morphology. Settlement: establishes relationships between land use and communication lines. The form and function of the time course.
1912	Hassinger	Draw attention to density residential land use and structure to solve the problems associated with the protection of cities.
1918	Geisler-Martiny	Examine the types of buildings and city plans in a morph graphic classification. Topographic and geographic definitions of urban perspectives.
1927	Bobek	- Reviewing the key features of citiethat change over time depending on the form and function.
1941	Scharlau	The city plans to investigate the formation of landuse cadastral plans.
1949	M.R.G. Conzen	To draw forms and interpret the underlying process of shaping. Examine the structural condition of the existing town planning by examining the historical development.
1967	Whitehand	Structural analysis of tissue changes, combined with the work of other individuals, architects and developers

Novel studies regarding urban morphology from an architectural perspective are demonstrated in table 3, as follows [5].

Table 3: the theories of urban morphology.

Date	Author	Conclusions
1780	Durand	Language is a merger of repetitive static form, dysfunctional or formal restrictions.
1828	Blondel, Boulle and Ledoux	Based on the architecture reveals a type of function.
1910	Muratori	Analysis of the built environment concept at various scales. Typo-morphology studies
1933	Caniggia	Typological process of urban development in the evolution of form component types and components of contex
1960	Argan	The formation of specific types of structure occurs due to a series of functional and morphological similarities between them.
1970	Rossi and Krier	Study of the urban texture of typological process and how it affects building structures.
1980	Moudon	Ideological, cultural and economic variations in form which differs according to the city in time.
1980	Hillier	Connected to each other in the axial analysis method based on its spatial relationship to each other and the urban fabric of premises

The theoretical foundations of urban morphology rose from classics published and can be chronologically ordered as demonstrated in table 4, [3].

Table 4: the publications of urban morphology [3].

Index	Year	Author	Title
1	1959	SaverioMuratori	Studi per unaoperantestoriaurbana di Venezia
2	1960	MRG Conzen	Alnwick town-plan
3	1960	Kevin lynch	The image of the city
4	1961	Gordon Cullen	Townscape
5	1961	Jane Jacobs	The Death and Life of Great American Cities
6	1961	Aldo Rossi	L' Architettura Della Cittá
7	1977	Jean Castex, Jean–Charles Depaule and Philippe Panerai	FormesUrbaines: De L'îlot à La Barr

8	1984	Bill Hillier and Julienne Hanson	The logic of space

The spatial evolution is viewed from the perspective of growth from the historical core, following the significance of collecting relevant information for the preparation of an adequate practice catalogue for increasing the compatibility of urban morphological research [5].

Essentially, studies on nearby cities in the region, i.e. Erbil following similar analogy of political events as the main factor distinguishing growth stages are detailed in table 5, [3].

Table 5: Sulaimani development stages [3].

Phase	Period
I	1947-1957
II	1958-1977
III	1978-1987
IV	1988-2017
V	2017-present

For Sulaimani, in February 2006, a consortium of German planners and engineers was commissioned for the new master plan. This project is finalized with maps and recommendations in 2009 as in a report (Master Plan Report (MPR), 2009), based on studying urban development. From a geographical perspective, the pattern of the city urban growth and its stages have been discussed in detail by Al-Qayim et al, dividing the growth of the city into three respective stages: Old (1920 – 1973), Modernization (1973 – 1990), and Stabilization (post – 1990). As shown in Figure 11, in the Appendix.

However other urban researchers used time periods adjusted with the scope of their studies of transforming residential land uses, as shown in table 6, and from a historical background, the following division was incorporated in the studies: [6]

Table 6: Sulaimani development stages [6].

Phase	Time period
I	2009-2019
II	2020-2029
III	2030-2039

On a more sophisticated level of analysis, incorporating GIS for studying landuse, Sivan et al have defined growth stages into relatively smaller divisions to capture the states of landuse development, as shown in table 7, below, [3].

Table 7: Sulaimani: development stages [3].

Phase	Period
I	1925-1990
II	1991-2003
III	2004-2007
IV	2008-2013
V	2004-2018
VI	2019-present

Contemporarily, in order to draw conclusions, the author proposes the following organization formulated on the basis of quality survey analysis discussed with experts regarding the major factors influencing the physical development of the city.

Table 8: Sulaimani: development stages.

Phase	Time period
Ottoman reign	1299 – 1917
British reign	1918 – 1963
Ba'ath reign	1964 – 2003

Sovereignty	2004 – present

In an attempt to classify the traditional residential types, local researchers are two primary types. The first type is produced by one parcel and open space is located in the middle of the parcel, while the second type of courtyard is consisted of more than one parcel and separated by a fence. Figure img illustrates the classification in detail. [5] The survey of more than 6 thousand of historical houses, 62% were two stories, while the majority of these houses were faced south – south east, usually included a manually dug well. The area details sown in table 9. And Table demonstrates the typology of the traditional houses in the city [7].

Table 9: sulaimani building type facts.

Element	Minimum area (m2)	Maximum area (m2)
Building	23	266
Parcel	41.6	1,009

The building forms classified are detailed in table 13 in the Appendix, following figure 14, which breaks down the number of buildings per the dimension of the building forms.

5. Materials and Methods

In this study, a number of hypotheses have been established following the collection of historical and modern data in various formats relevant to the scope of research; spatial development of Sulaimani city. The list of research hypotheses follows:

- The major driving factor that influenced the overall development of Sulaimani city as well as the other areas in the region was in fact politics. Therefore, the temporal axis of comparison of the historical analysis has to be adjusted with the timeline of governing authorities.
- The earliest abstraction of the city has to be followed as a spatial reference regardless of accuracy as a result of technical methods used for mapping at the time, because these guidelines and axis represent the origins of the city in which we can see the evolution when more recent maps are laid out within the same extents.

Lite The approach taken in this study is aimed at setting up the default environment for potential comparative analysis on different scales while taking diverse factors into account,

(1) Setting up timeframe for analysis based on previous literature

(2) Collection of imagery and graphics and organizing them according to established time frame, in the preprocessing phase as a number of the acquired images were digitized from raster to vector due later processing requirements in GIS.

(3) The theories and classifications presented in previous studies have been formulated in a quantitative survey while engaging experts to evaluate the study area on such basis.

(4) As a result of the spatial analysis, the derived information have been displayed in the form of conclusions, graphs, charts and thematic maps to demonstrate the gaps and findings. View Figure 13, in the Appendix.

The Integration of all available historical and housing-relevant Data regarding population demographic and residential land-use development within the Geographic Information System. Which can be demonstrated simple workflow is shown in Figure 15, in the Appendix.

Moreover, from the technical perspective, the preprocessing flows include the conversion of spatial information from one format into another in order to be utilized for efficient analysis using GIS tools and methods, which can be detailed as smaller specific steps shown in Figure 16, in the Appendix.

The basemap used as a reference has been placed conventionally following the initial system documentation as demonstrated in Figure 17, in the Appendix.

The research has been conducted through the application of GIS system in urban planning. ArcGIS Pro version was used for spatial analysis of the study area. With regards to the attributes within the geographical database, SPSS was used for further statistical analysis for presenting the questionnaire survey results.

In terms of spatial reference, the previous researches show how the spatial development of Sulaimani city has taken several stages of growth under the influence of major driving factors, including politics and economy which reflect the major events that occurred in the region. And this evolution has been divided into a number of phases. Various references have been used in the different studies and project measurements In such a sense, this novel study reconstructs a timeframe concluding all of the available data form multiple sources, as shown in Table 3-3. The geographic reference established to model the morphology of Sulaimani city is based on a base map issued by ArcGIS Map Server with the projection system of WGS 1984 Web Mercator (auxiliary sphere) a variant of UTM. The form of the city can be analyzed using reference guides consisting of two major axis and a central point located at the coordinates.

The process of locating digitized imagery at their exact geographic locations requires establishing spatial links between control points with their corresponding reference points of known coordinates on the basemap used in the GIS system. While more points introduce errors, adding more than the recommended number of minimum points, three, increases the accuracy of the output rectified image [8]. Historical maps have been initially developed with lower means of accuracy due to the technics and methods used at the time, hence higher orders of polynomial transformations are required to shift, scale, rotate, and reduce any distortions while overlaying the map layers for analysis. This study incorporates the use of the formula shown below while following the highest neighbor resampling method in the third-order transformation.

$$x=f\_1\ (x,y) \qquad (1)$$

$$y=f\_2\ (x,y) \qquad (2)$$

While;
x,y : input image coordinates (column, row)
X, Y : map coordinates
f_1,f_2 : transformation formula [9]

Georeferencing involves transforming a digital image to match with true location and dimensions. These mathematical operations has several methods based on the required adjustments for correcting the distortions. Zero-order uses one matching point with a point in a certain reference map in order to relocate the image, while other differential calculations for shifting, rescaling and rotating the image involves higher order of polynomial transformations, the following formula is used to determine the minimum number of control points required to achieve a certain order:

$$N=((n+1)(n+2))/2 \qquad (3)$$

While;
N : number of ground control points
n: transformation order

Even though the Affline method is considered the most common, which involves bilinear transformations including orthogonal shift, scaling and rotation of X, and Y axis. However, regarding the low-quality of available imagery, Polynomial method of the third order was used which demands 10 control points, notwithstanding an additional number of 7 points was observed and taken into calculations for the purpose of error reduction and increased accuracy.

In the process of map production, several multi-temporal images were digitized in GIS for built features in order to study physical growth. The input data used was rectified satellite imagery obtained from Sulaimani city municipality in the years of 2006, 2007, 2010, 2012, and 2014. These images are comprised of 8-bit multi-spectral bands accessed in (.png), (.JFIF) and (.tiff) formats with the resolutions of 4, 3, 3, 3 and 4 meters cell size, respectfully. The software used for spatial analysis in this study is

Esri's ArcGIS Pro 10.3 supported by 64-bit Microsoft Windows version [10]. After data collection from a number of experts have been interviewed regarding their relevant experiences to fill the survey following consent, IBM SPSS statistics software, version 28.0.1.1 [11] was used to present results. Based on knowledge and evidence, model the evolution of Sulaimani in a conceptual approach using a model drawn by the previous theories. The criteria are coded to be processed afterward to output graphs and diagrams displaying the developments [12].

The survey is divided into four main parts, subsequent to background information, the form consists of a group of criterions regarding the classification of Sulaimani to type the Physical Development Directions, Urban Structure Models, Development Patterns and Forms. Following development of the city, which concerns the direction of spatial growth, primary driving factors, the obstacles and their specifications, as well as development pace during different periods of time, and residential landuse preferences in terms of location and types.

Finally, a number of hypothetical statements are assessed in the format of to which extent participants agree or disagree with the idea, including:

- Residential is the most common type of landuse in Sulaimani city.
- The residential landuses of the city of Sulaimani is currently developing.
- Rapid growth of the city has negative consequences.
- There are sufficient vacant lands and expansion areas for future development in Sulaimani.
- Population size of Sulaimani city is growing.
- Population and urban growth are balanced and due to development plans of Sulaimani city.
- The historical districts of Sulaimani city are preserved.
- The spatial extents, urban form, size and geographical area of Sulaimani city should be retained within certain limits.
- Residence proximity to CBD is considered ideal.
- New areas established in Sulaimani can alternate the historic central CBD.
- Certain regions of Sulaimani city has experienced a relatively more rapid growth.
- The form of Sulaimani city has been distorted due spatial development.

5. Results

The survey questionnaire result is shown in Table 10 below. For the statements tested according to the research framework:

Table 10: the survey questionnaire statements.

No.	Statement
1	Residential is the most common type of landuse in Sulaimani city.
2	The residential landuses of the city of Sulaimani is currently developing.
3	Rapid growth of the city has negative consequences.
4	There are sufficient vacant lands and expansion areas for future development in Sulaimani.
5	Population size of Sulaimani city is growing.
6	Population and urban growth are balanced and due to development plans of Sulaimani city.
7	The historical districts of Sulaimani city are preserved.
8	The spatial extents, urban form, size and geographical area of Sulaimani city should be retained within certain limits.
9	Residence proximity to CBD is considered ideal.
10	New areas established in Sulaimani can alternate the historic central CBD.
11	Certain regions of Sulaimani city have experienced a relatively more rapid growth.
12	The form of Sulaimani city has been distorted due spatial development.

Table 11: the statements results distribution.

State-ment	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	0	0	0	0	12
2	0	0	0	0	13
3	0	0	0	3	10
4	0	12	8	0	0
5	0	0	0	3	10
6	0	16	4	0	0
7	0	12	8	0	0
8	0	0	4	5	2
9	0	0	4	3	6
10	0	0	2	3	3
11	0	0	0	0	10
12	1	0	0	1	16

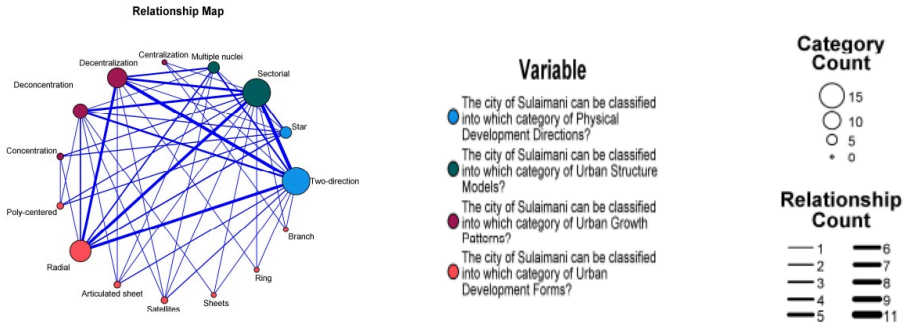

Figure 1: The Survey Questionnaire results.

Following the morphological study of Sulaimani city, the residential landuse transformations can be historically traced as shown in the diagrams of Figures, 2, 3, 4, 5, respectfully.

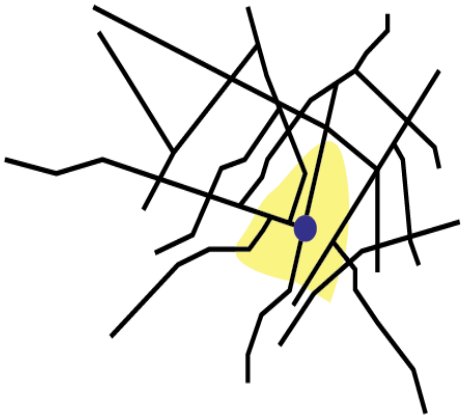

Figure 2: Phase i, Sulaimani city has been established initially in 1784 with a central cluster of commercial Bazaar Qeyseries located in proximity to residential rural settlements of Melkendy and army camps on the north in Qelachiwalan.

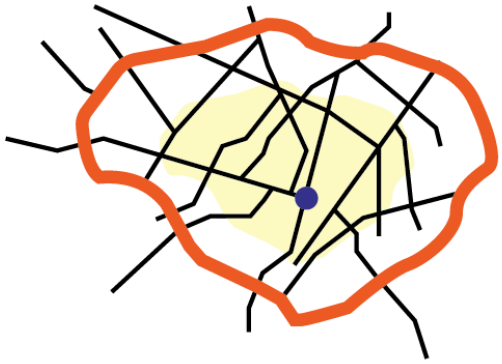

Figure 3: Phase ii, Development occurred despite population fluctuations caused by conflicts and political instability over the years. The spatial significance of the city and relative advantage in comparison with other regions under the circumstances influenced immigration.

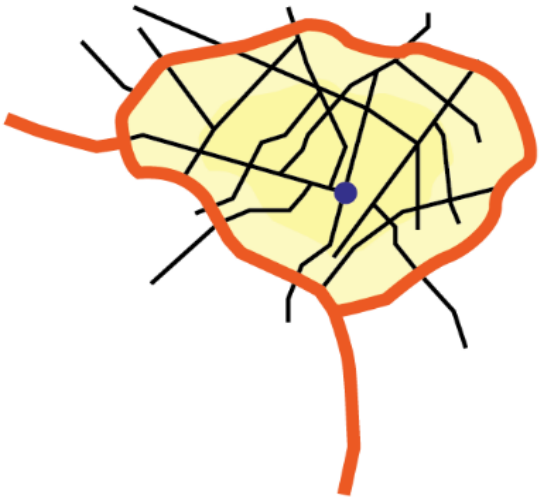

Figure 4: Phase iii, The city grew to fill the established 60m road border while frequently concentrating consistent pressure on the overcrowded center.

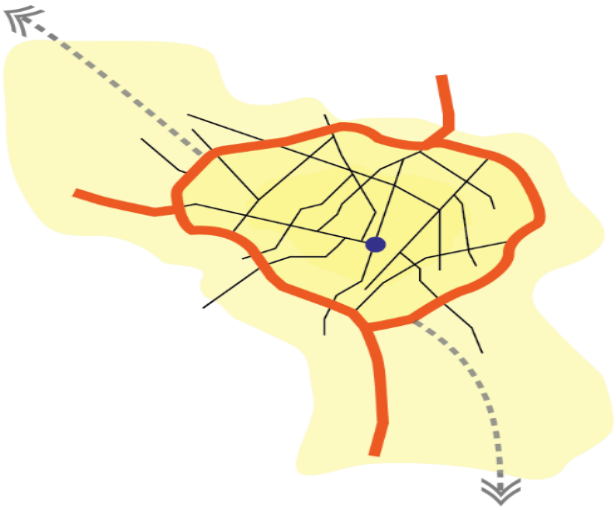

Figure 5: Phase iv, following 2003 and decline of the authorities, rapid urban sprawl resulted from two directional development in a decentralized manner.

6. Discussion

In modern times, Sulaimani is one of the largest Iraqi cities in Kurdistan region located at latitude and longitude of 35° 33′ 26″ N, 45° 26′ 8″ E, respectively between Azamar-Goizha mountain ranges on the northeast and Baranan series which extends from east to west, south of the city. Similar to other Kurdish cities in the region, the layout of administrative boundaries has always been under political influence, there is a notable disruption in the organizational structure due to the mass relocation of native populations within 30 km distance from the eastern border of the nation, in the periods of 1970s until the national Iraqi-Iran war in 1988. [13]

The Kurds were historically split between the largest ruling. In such a sense, while Sulaimani is a comparatively recent city, there are no excellent accurate demographic records. Multiple sources provide somewhat different numbers. On average, the city now is about 2 million inhabitants composed of people from major Kurdish tribal groups such as Bajjlan, Bayyat, Berzenchi, Hamawand, Hawraman, Jaff, Jibari, Shewann, Zengana in addition to Ardalan immigrants as well as Arabs, Armenian, Assyrians, Chaladeans, and Turks.

From a religious point of view, Sunni islam is predominant among other groups of Shia, chaladin Christians, al-haq minorities [6]. Multiple sources have illustrated the size of population, however the exact number of populations to date is not officially recorded due a number of reasons, e.g. financial shortage, accuracy of methods and negative political influence. Approximately, regarding all of the sources combined, the population of Sulaimani at 2023 is estimated to exceed two million people. Current livelihood indicators of result from the series of national and local events experienced by the population which was initially formed from an interestingly diverse cultural background of immigrants to the 'new promising city', the inhabitants of the city are almost evenly distributed between the genders of Male and Female, however, there are slightly more younger males than females. Regarding child mortality. Studies of 2018 has shown 8 deaths per thousand, in comparison with Iraq statistics being 23. The active working class, which forms nearly 64.9% of the population, is considered to be above 15 years old in which the rate of unemployment is 5.6%. [13][14]

Besides religious divisions, the society was composed of three classes regarding family income and ownership of properties. Major social groups included of which is defined based on religious views, such as the Muslims, as well as the Christians, who in contrast to the Jews, blended well into the social fabric to a point of being almost non-distinguishable except for in their occasional religious events and rituals. Another hierarchy was related to the concept of "Tariqat; the path", a social organization system that ranks individual members of certain families in terms of religious education and status, thus the majority group of Muslim could be classified either into 'Sheikh' or 'Mizgen'. The second class were the wealthy merchants from diverse ethnic groups, whom gained family names based on their type of business and industry including, Qazzaz, Qasab. Political and administrative positions also upgraded the social status of families, such as the role of Mutasarif, head of the municipality.

The multilingual community inherited its communication through inheritance, literacy and blending of the diverse families, the languages of Kurdish, Arabic and Turkish almost practiced at the same level while the knowledge of more than the native language or accent displayed status.

Essentially, in addition to military and political interest at the time of the Ottoman reign, the location of the city resembled a frontier connecting many international trade routes of goods. Notwithstanding the main function of The built fabric was to provide residence for the community mainly involved in commerce and industry as a comparatively modern alternative to the rural lifestyle of the surrounding villages based on livestock and agriculture, the physical form of these buildings follow its associated parcel boundaries divided due land occupations then eventually shaped by ownership documents and transportation regulations. [5]

From the south-east, the oldest route to Halabjacity, was connected to the central core of Sulaymanyah in addition to Qaradagh road from the south which accessed the surrounding towns under the governorate of the city. The residential and commercial parcels of the established mixed-use core were defined by the primary surrounding roads which were developed to organize the growth of territorial boundaries, such as Sabunkaran Road was upgraded in 1921 by widening Sabunkaran to Kaniaskan path. From the 1930s until 1960s, several roads were constructed to connect the city to the surrounding cities in the region through trade and industry which modified the physical form of the city.

After building Peramed road in 1944, Mawlawi and Kawa streets were developed as the primary straight roads dividing the central block into smaller ownership groups. Despite redistributions by the municipality, some of the parcels were eventually demolished for road widening and parking. Kawa road was constructed to accommodate mobility from southern neighborhoods, i.e. Sabunkaran, extended by Haji Mala Ali road in the 1950s, as well as several parallel paths crossing this main road to join the prospective new residential land-uses occupied, namely in 1957, the neighborhoods of Iskan, Majid bag, Twi Malik, and Khabat were built.

From the southeast, the oldest route to Halabja city was connected to the central core of Sulaymanyah in addition to Qaradagh road from the south which accessed the surrounding towns under the governorate of the city [5]. Following the city expansion to the northwest along the Kirkuk highway, several public and administrative buildings on Mamostayan Street transformed the city as a part of developments issued in the Sulaimaniyah master plan of Doxiadis in 1958 which also proposed 100m ring road. The infrastructure was further developed in the city in the first phase, due to the construction of the university, hospitals, and additional neighborhoods in 1968. Spatial growth occurred in a circular form until the 1980s. See Figure 10, in the Appendix.

Following the policies of 1981 in the second phase, which restricted the city's future expansion through marking the established 60m road as a limit, under the grounds of taking security measures and utilized the adjacent landuses for military purposes until 1991, following the political events, this decision was canceled by the municipality. After that in the third phase, which is still effective in the contemporary form, the core of the city is composed of eight neighborhoods, Malik Kandi, Sabunkaran, KaniAskan, Sarshaqam, Jwlakan, Dargazen, Bazrgani and Shexan, covering almost 2 thousand kilometers square. The plots of these historic neighborhoods are accessed by narrow alleys and cul-de-sacs. Each neighborhood has its own religious building, local shops, and clusters of one or two-story houses assembled organically. Muslims, Jewish, and Christians resided in different directions of the old city. Jwlakan and Gawran neighborhoods were reserved for Jewish and Christians, respectfully. [5]

Initially, the central part of the city served as a vital commercial core surrounded by traditional residential settlements. The city was connected to the trade centers of adjacent cities by trade routes, these international routes directly accessed the neighborhoods through very narrow alleys and defined distinctive neighborhoods in the city. Hence in the fourth phase, the community of diverse ethnic groups settled in the different neighborhoods of the city in terms of location. The south was occupied by Jews, the east by Christians, and the rest of the city was dominated by Muslims. Moreover, rich families or members of the authority occupied large ownership parcels as well as surrounding rural families holding agricultural lands spanning over large areas. The major spatial development of the

city was driven in the direction of trade and commerce regarding proximity to ports in the import and export of goods.

In the fifth phase of transportation development and during the period of British rule, following the first world war, carriages were mostly replaced by motor vehicles due to traffic demands. Hence, following modernism, in the early 1930s, the city adopted new regulations regarding the inclusion of new transportation modes. Hence transformations, such as road construction and widening of the convenient paths were required to facilitate vehicular transportation. Moving on the built fabric integrated a network of streets construction of while new neighborhoods were organized in the form of buildings and plots. In addition to the housing projects developed as a result of private sector investment in Sulaimani, a number of public projects were built in relatively earlier periods of time, mainly financed and developed by three parties, Sulaimani Municipality, KRG Investment board, and KRG Ministry of housing and transportation.

The first project was in Sarchnar District in 1842, for workers of the factories and other potential industrial projects, however, landuses were not exclusively designed to accommodate the associated functions of the 422 houses established. Following a number of housing projects issued on landuses not intended for residents in the development plans, including green areas, as a result, the conventional process of allocation did not start with compliance with development objectives and authorized city plans, in fact, the city plans have been attached with alteration permits of the landuses. Notwithstanding the documentation process, which also did not ensure the recording of all of the changes, consequently not updating the maps of the city. [6]

Figure 12 shows the location and size of housing projects per original developing party. These relatively remote locations were selected considering the availability of large-scale vacant lands, after construction, these locations attracted infrastructure and expanded the city aligned with private parties replicating the process through smaller and eventual projects spanning over wider extents.

Most of the projects have been granted urban lands and modified their land-use types in favor of established terms such as financing or execution of public infrastructure projects, i.e. intersections. All of these developments were issued in the form of an update rather than a commitment to previous land-use development plans as a reference. This case indicated the influence of the market and housing demand over the morphological form of the city, and the planning authorities do not enforce a certain form, but rather allow adaptation to any initiative financially capable of building and renovations.

One drawback of these housing clusters is the issues related to ownership permits, as in the traditional land tenure system of horizontal construction the owner can inherit their land as a property registered as valid in the government administration directly associated with the end-user and connected to the public infrastructure, notwithstanding allowed modifications and upgraded, such as the use of power supply, i.e. generator, construction of additional building floors, digging wells, ..etc. While conversely, private projects have the third-party developer company as an intermediate between the government and the inhabitant. Moreover, from a legal perspective, the challenge of ownership remains open [15].

Despite the absence of a formal timeline for the development of Sulaimani city, previous geomorphological researches divide the stages into The old Stage (1920 – 1973), Modernization (1973 – 1990), and Stabilization (post – 1990). [16] Furthermore in order to capture the state more accurately, the urban residential development of Sulaimani city can be organized by distributing into four historical phases based on political influence, as shown in table 12.

Previous studies organize the development stages in different methods as shown in Figure 11. However, Table 12 shows the proposed timeframe suitable as a reference for both historical and prospective spatial studies.

Table 12: Sulaimani: proposed development timeline.

Phase	Year	Source	Description
i	1784	[13]	The city was constructed from basic rural settlements.
ii	1785 – 1957 *		Residential landuses grew with an emerging immigrant population The 14th July revolution of coup d'état caused a shift in power from British monarchy to pan-Arabic military rule
	1958 – 1984		Political instability, ethnic segregation, and conflict of Mousil City disturbed demographic and spatial balance in the surrounding regions
iii	1985 – 1998	[14]	The attempt of the authoritarian regime to control the growth of the city by circling it spatially
	1999 – 2003		
iv	2004 – 2007		Population growth continued to develop residential landuses in addition to government-subsidized housing programs for the families of war martyrs.
	2008 – 2013		
	2014 – 2018		The dominance of private sector investment in housing projects overridden landuses of the original master plan during the economic crisis post-ISIS war.
	2019 – 2023	[10]	

Notwithstanding the product of the remote analysis that was generated from satellite imagery captured in the years of 2006 onwards, up to 2014 the most recent masterplan of the city. These maps can be seen in Appendix A. Rapid growth in a pace of 20% almost every couple of years be been observed. Moving on in the period of 2014 – 2015, a masterplan was developed to plan for the land uses in the city, after an extensive study of resources, demand, and community vision to advance the urban status of Sulaimani, the land use plan was not addressed effectively and did not function resulting into a number of case problems including:

(a) Shift of historical residential lands to commercial uses: After the growth of the city, the core has become overcrowded and in the absence of effective preservation acts, many of the historical dwellings reportedly were demolished. Similarly, in the older neighborhoods where the families aged to a point of housing units becoming vacant, the houses on the roads permitted for commercial uses are instantly bought and replaced usually with high-story buildings, disrupting the other houses in the neighborhood with problems of traffic and car-parking. [5]

(b) Sprawl and over-run in the city outskirts:

While the historical migration from nearby villages and rural areas moving into the city continues. At certain periods of time under precarious political situations this flow has increased for the people seeking better conditions and the authorities distracted from properly hosting these communities at the correct locations, as a result of poor management, unaffordable housing, and the financial condition of those families, the outskirt regions of the city became occupied of overrun residential settlements that took advantage of the main lines of infrastructure that were planned for large-scale industrial development. Another wave of inner-city migrations further densified these illegal and unplanned settlements after being pulled from their origins due to land-use change. See Figure 13, in the Appendix, in order to preview the rapid growth captured on satellite imagery of Sulaimani.

(c) Private housing projects:

The process of developing housing projects by the private sector requires feasibility studies, design plans, and legal approval from several sectors of the government in order to assess whether the investment is compatible with the established objectives of the current authorities as well as its possible to attain the intended advantages. However, the mechanism is currently flawed because the sequence of the process steps does not allow for the project to be reviewed by suitable experts in the correct order, and the documents and files are not being completely archived were required during the management flow, as a result, many projects get approved without proper assessment and checking whether it matches with the other designated plans or its possible spatial impacts.

While many lands are listed as under compensation and special subsidizing programs restrict the process of planning for development that provides solutions and promotes growth, among the major problems caused by this development is the occupation of green space and vacant lands by housing projects, this is not only degraded the urban quality by decreasing spaces but also created pressure and shortage on the infrastructure in the locations that were not planned to accommodate the large size of residents inhabiting these housing projects.

(d) Transportation routes:

As a matter of a fact, the advancement of transportation infrastructure includes the consumption of larger spaces for building new routes and intersections, which often includes using the residential land use types, and affects the nearby settlements indirectly due to the generated traffic and commercial demand that pulls the inhabitants to settle elsewhere while considering taking the financial opportunity of selling their occupied lands after it gained an increased value to be exchanged with the demand of land uses of commercial activities regarding proximity to travel routes.

7. Conclusions

Multiple methods used to visualize the spatial development of Sulaimani city since its original establishment up to date, as an initial step to analyze the city from a morphological point of view which provides a better understanding of the urban system and evaluate the existing situation before planning for its development. GIS allows for the possibility to process all of the maps and information layers to locate them in their correct geographical positions and overlay them on top of each other in order to view, compare and analyze their spatial influences accordingly. Moreover, the divergence can be determined as target areas with problems to be solved, since the changes that occurred can be further studied and the consequent need to issues addressed for solutions.

Historically the city of Sulaimani has spatial significance regarding its geographical context in the timeframe of political shifts of power that established this initial fortress city to grow rapidly and become one of the largest in the region which was relatively safer and more secure up to a point that it hosted immigrants and internally displaced population within its integrated community, creating a diverse spatial structure that was not modeled sufficiently up to recent due to a number of reasons

including lack of technology. Hence, nowadays with access to advanced technologies like GIS, we can effectively visualize the city from a spatial point of view in order to plan for its development and solve the problems and challenges addressed.

The residential development of the city of Sulaimani can be classified into four periods based on chronological ordering into the following periods: Ottoman reign (1784 – 1917), British reign (1917 – 1963), Ba'ath reign (1963 – 2003), and Sovereignty (2004 – present). The topography of the region incentivized the growth of the radial city form in two directions, northwest, and eastern south simultaneously along two major transport axes accessing the gateways of Sulaimani with linkage to other cities in the region. The negative aspects of development include private housing projects on the account of lands intended for different land uses based on development plans, the shift of historical residential lands to commercial uses as well as the sprawl and over-run in the city outskirts which disrupted public service facilities to be consistent with growth.

The ultimate approach for resolving spatial problems is through effective urban planning and monitoring through advanced technologies like GIS, following the cycle of planning which includes visualization of the current situation and constant updates with the changes that occur in terms of demographics and land use.

Data availability: Data will be made available on request.

Conflicts of interest: The authors declare that they have no known Competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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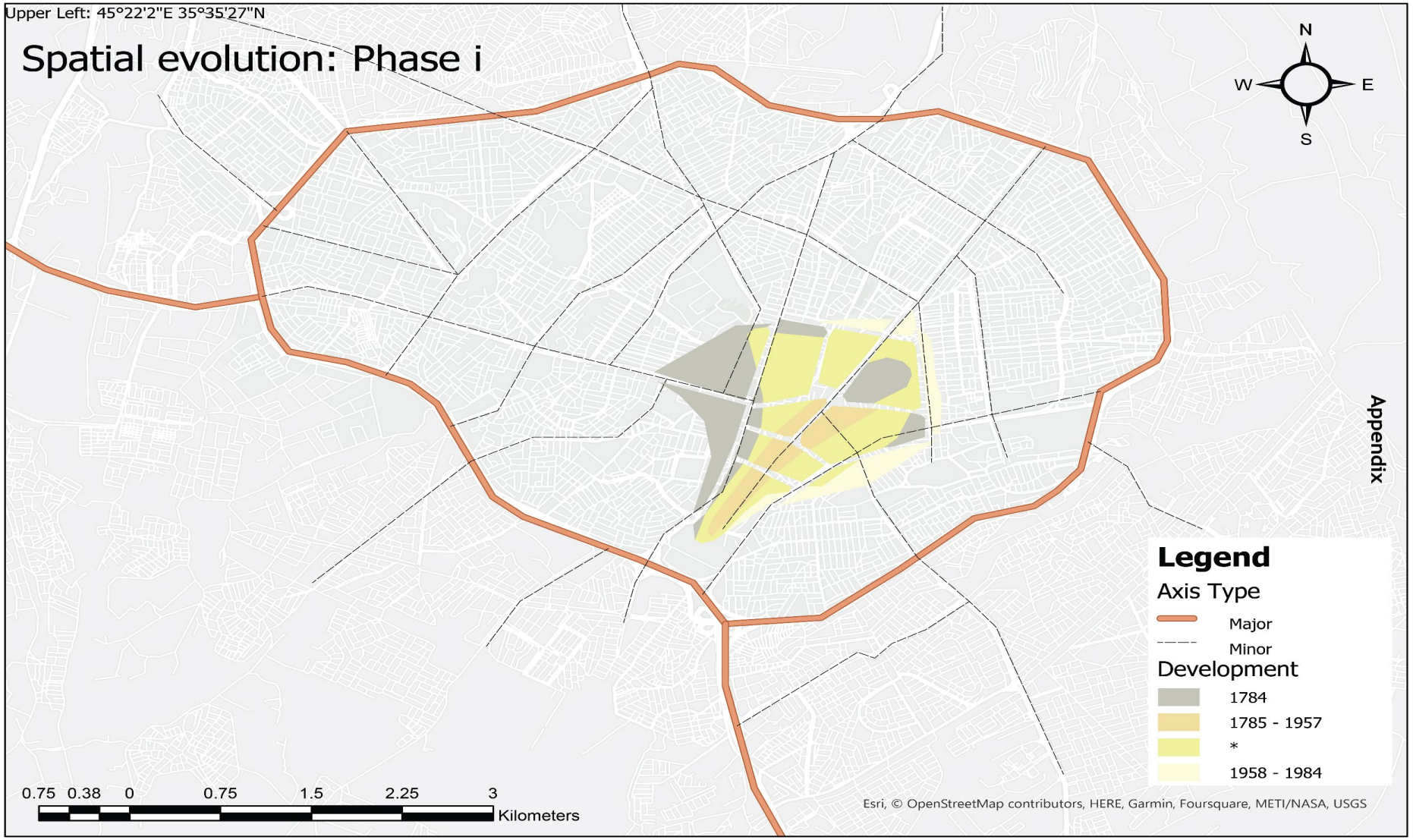

Figure 6: Map of Spatial evolution: Phase i. [RESEARCHER] .

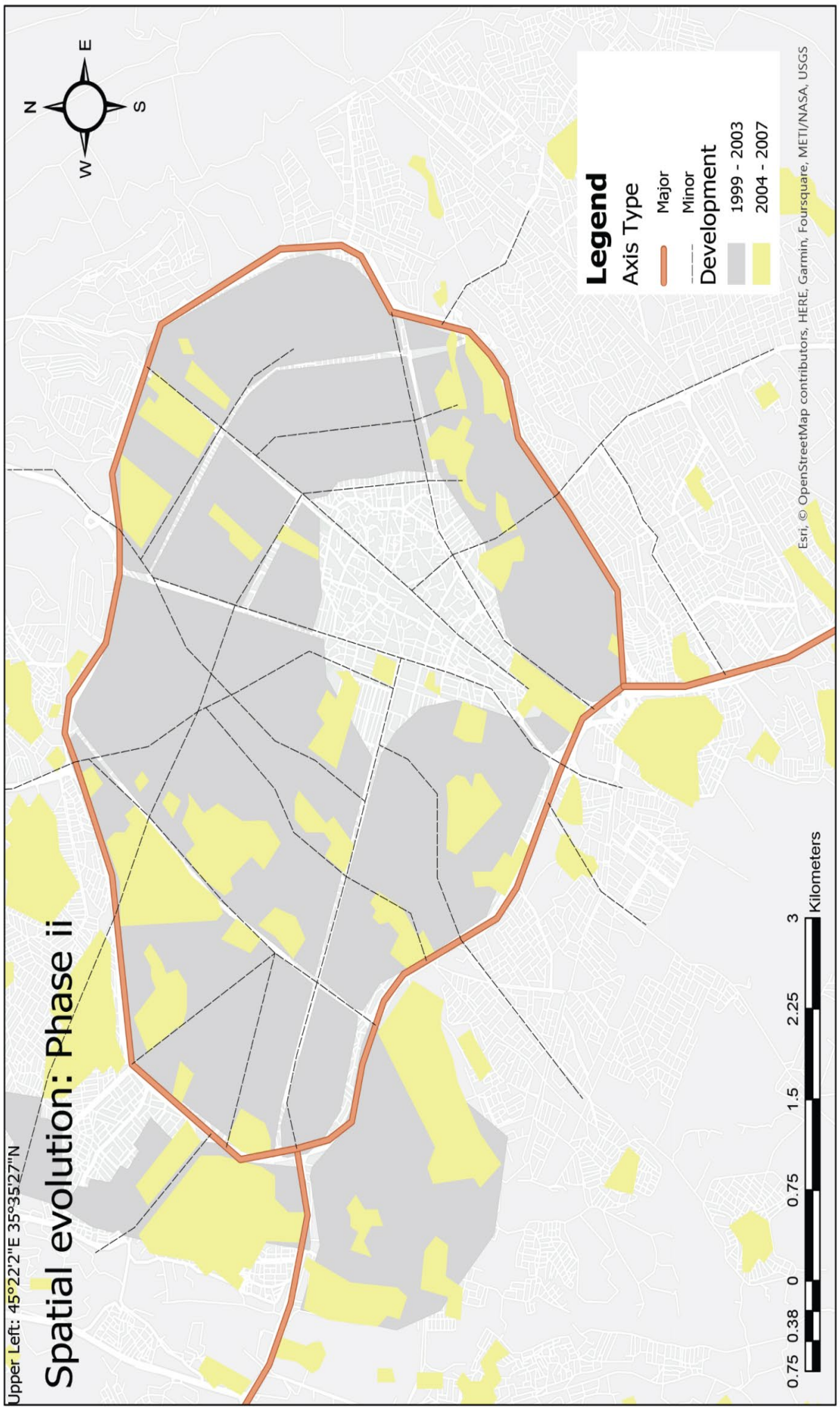

Figure 7: Map of Spatial evolution: Phase ii. [RESEARCHER] .

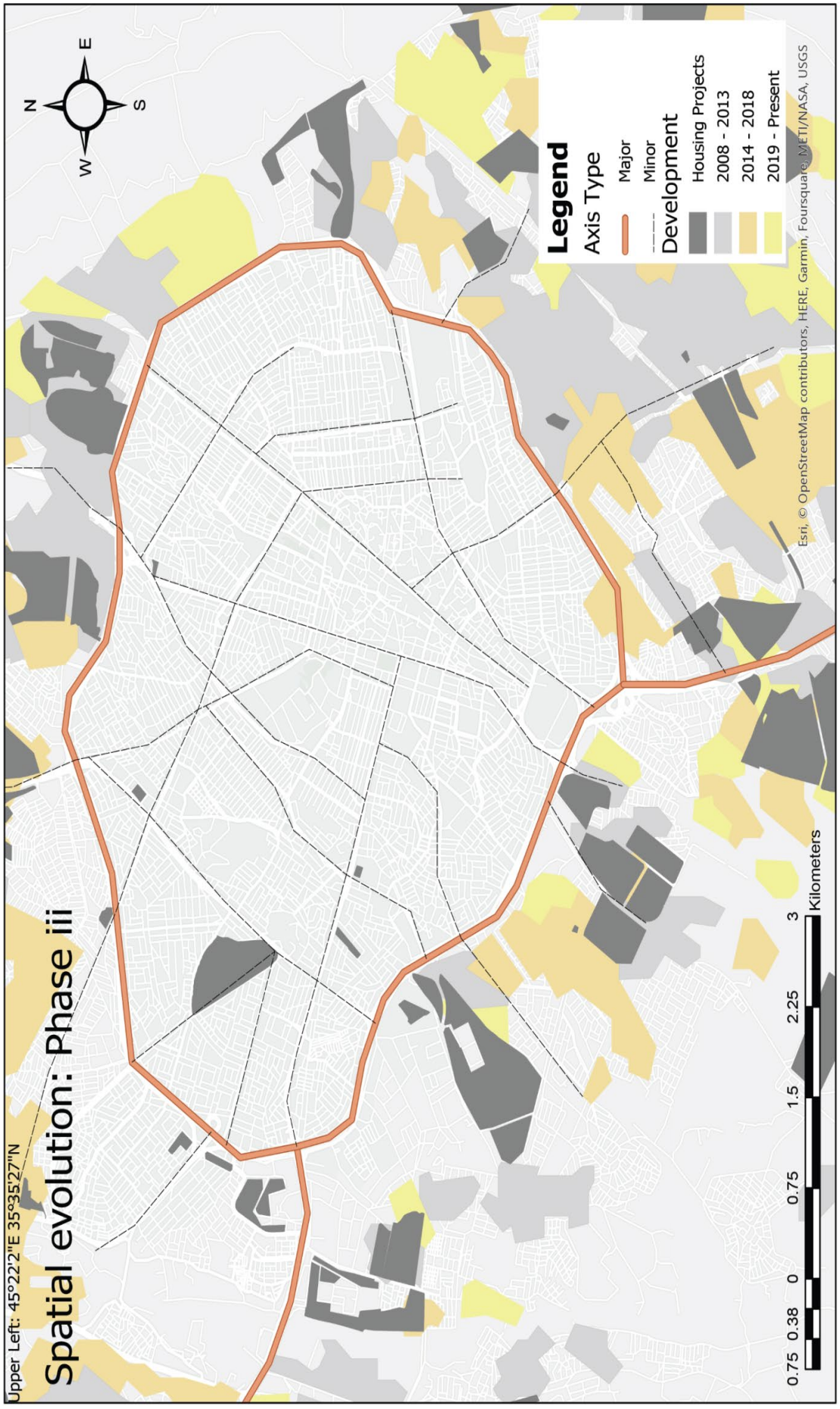

Figure 8: Map of Spatial evolution: Phase iii. [RESEARCHER].

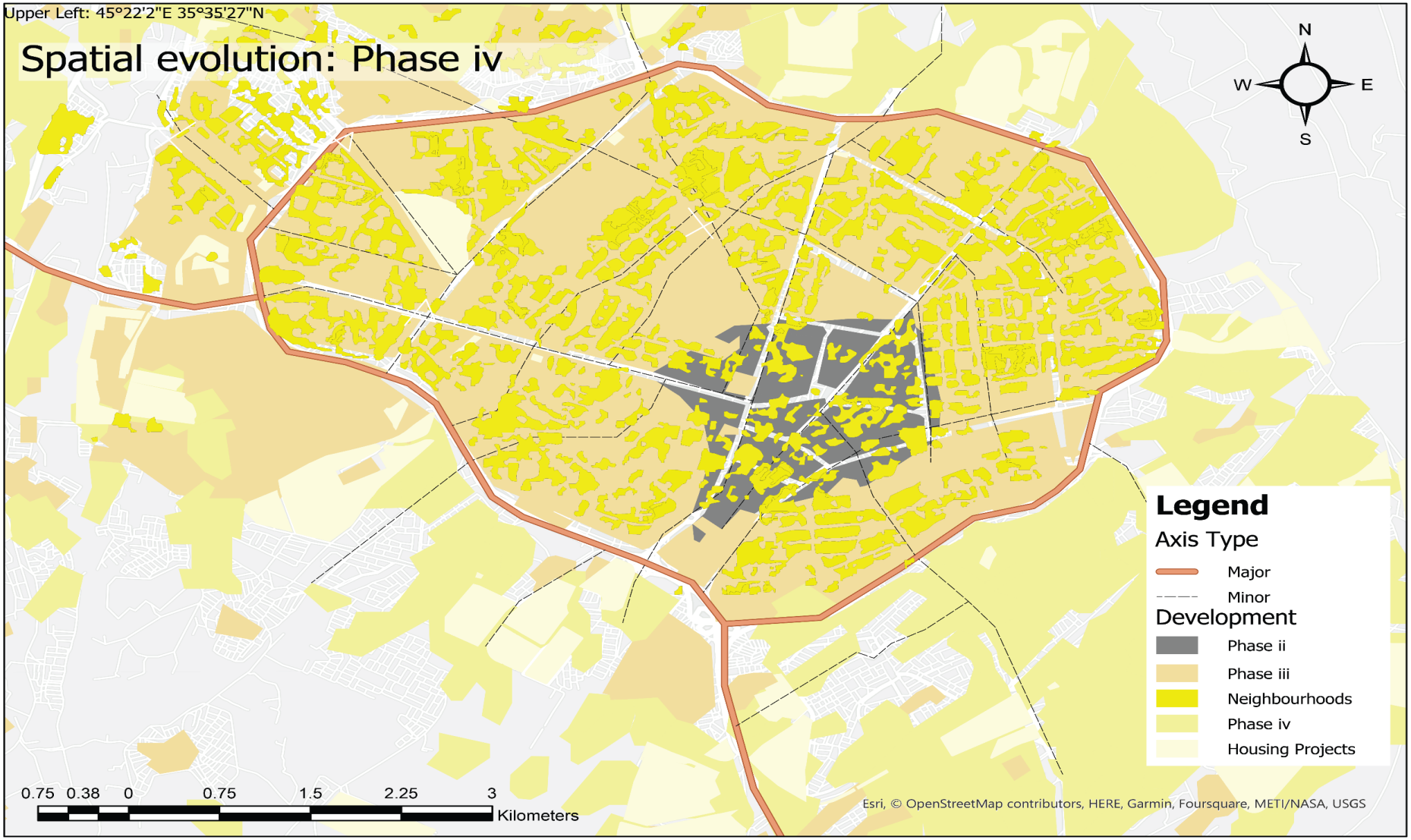

Figure 9: Map of Spatial evolution: Phase iv. [RESEARCHER].

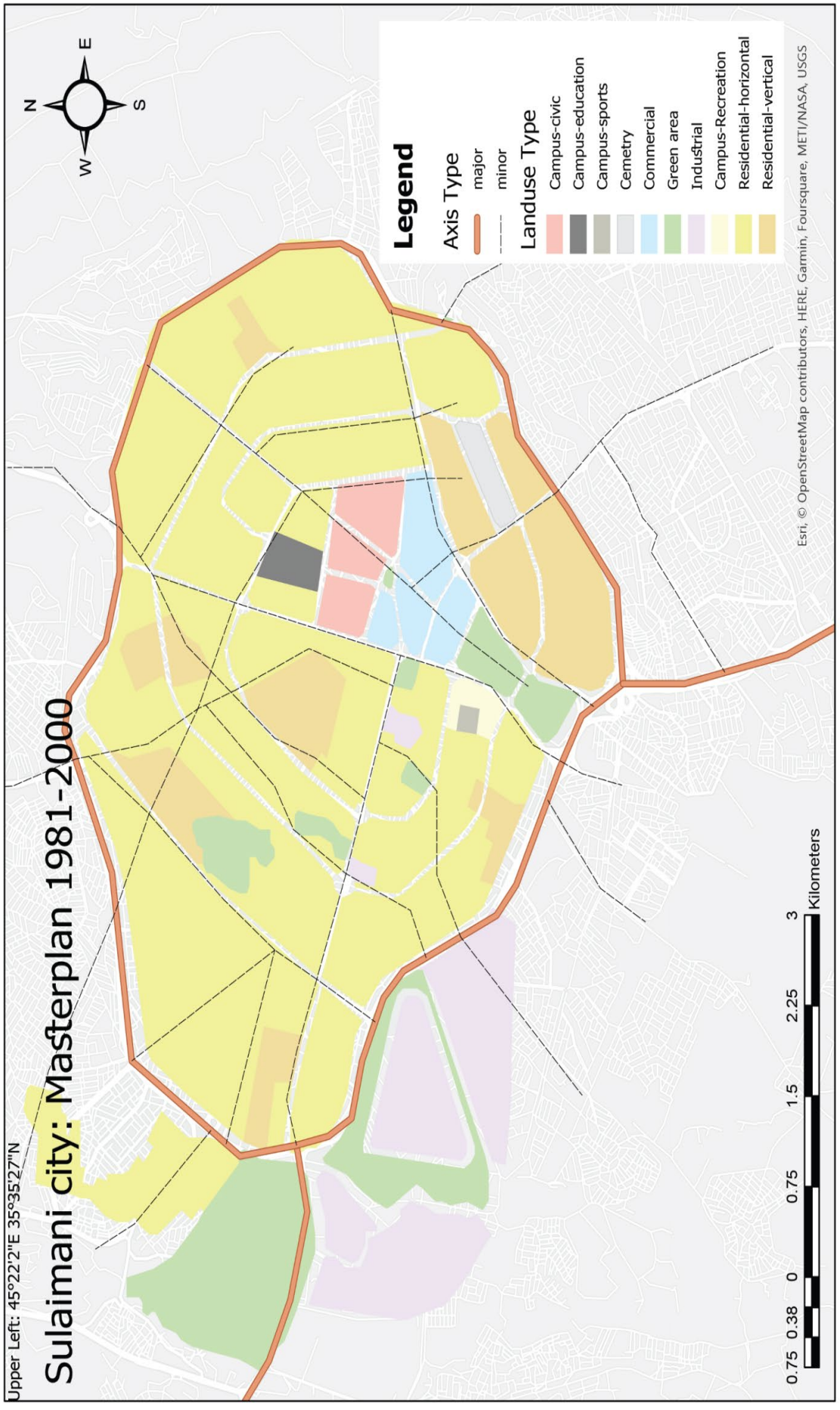

Figure 10: Sulaimani city Masterplan 1981-2000. [RESEARCHER].

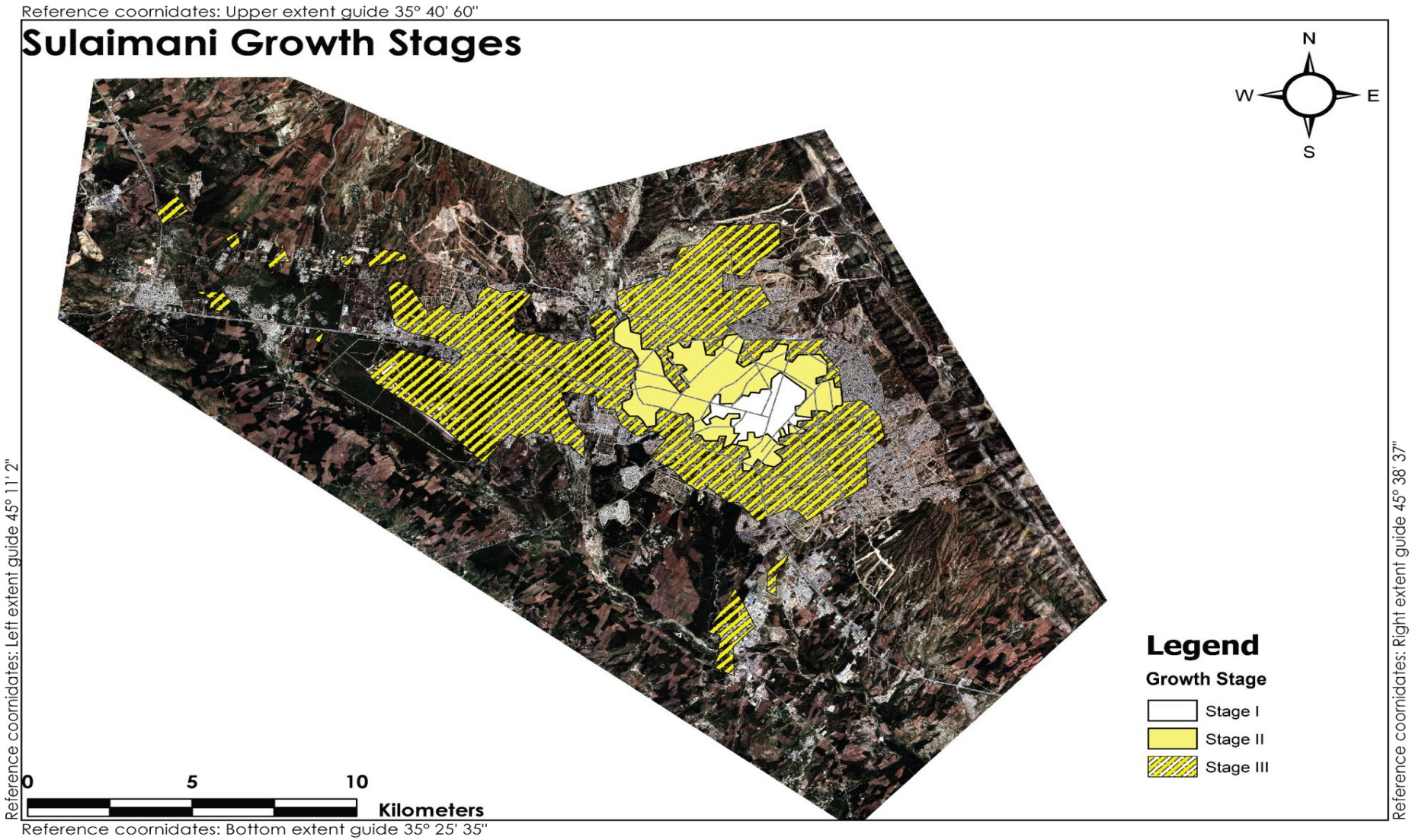

Figure 11: Sulaimani growth stages. [RESEARCHER] .

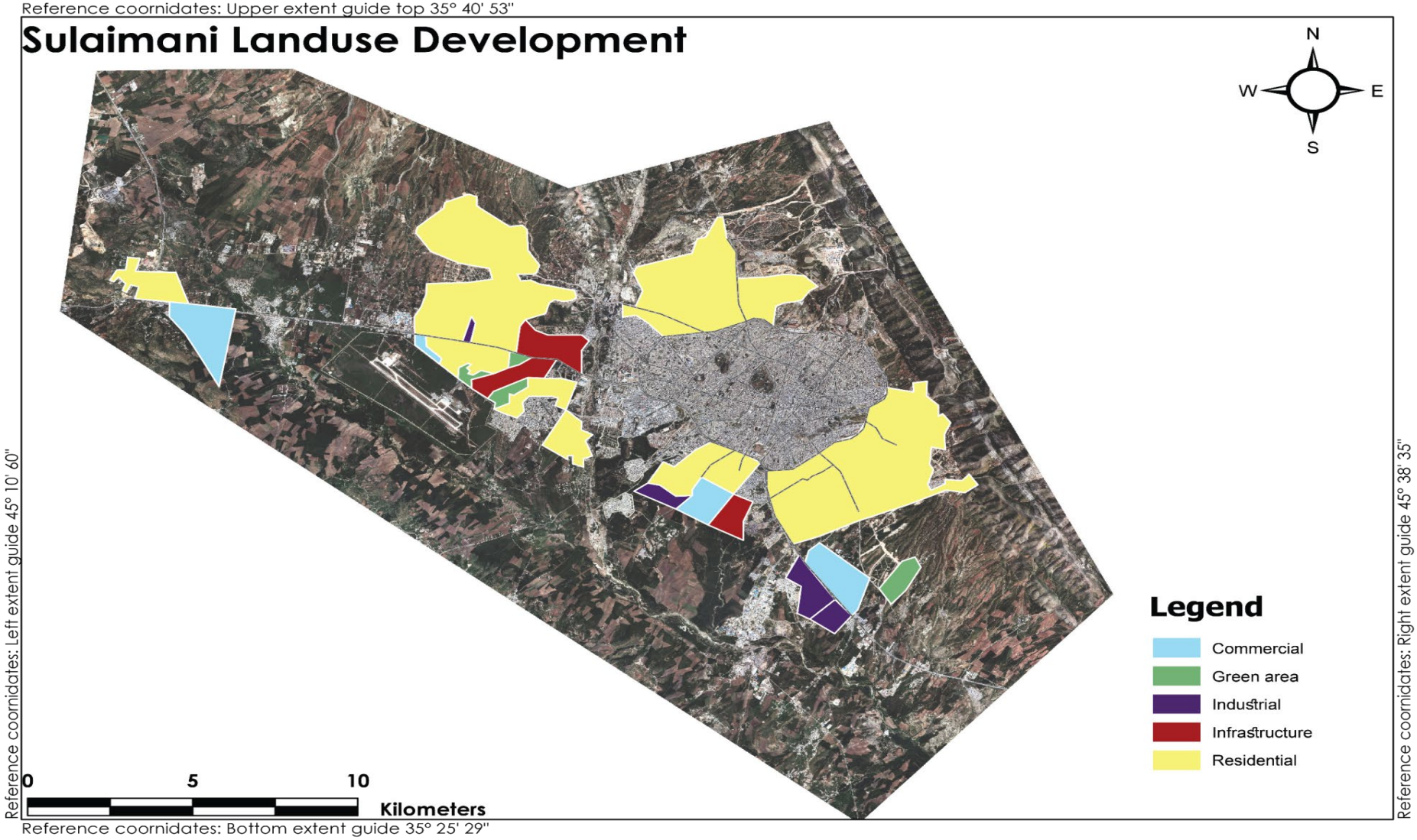

Figure 12: Sulaimanilanduse development. [RESEARCHER] .

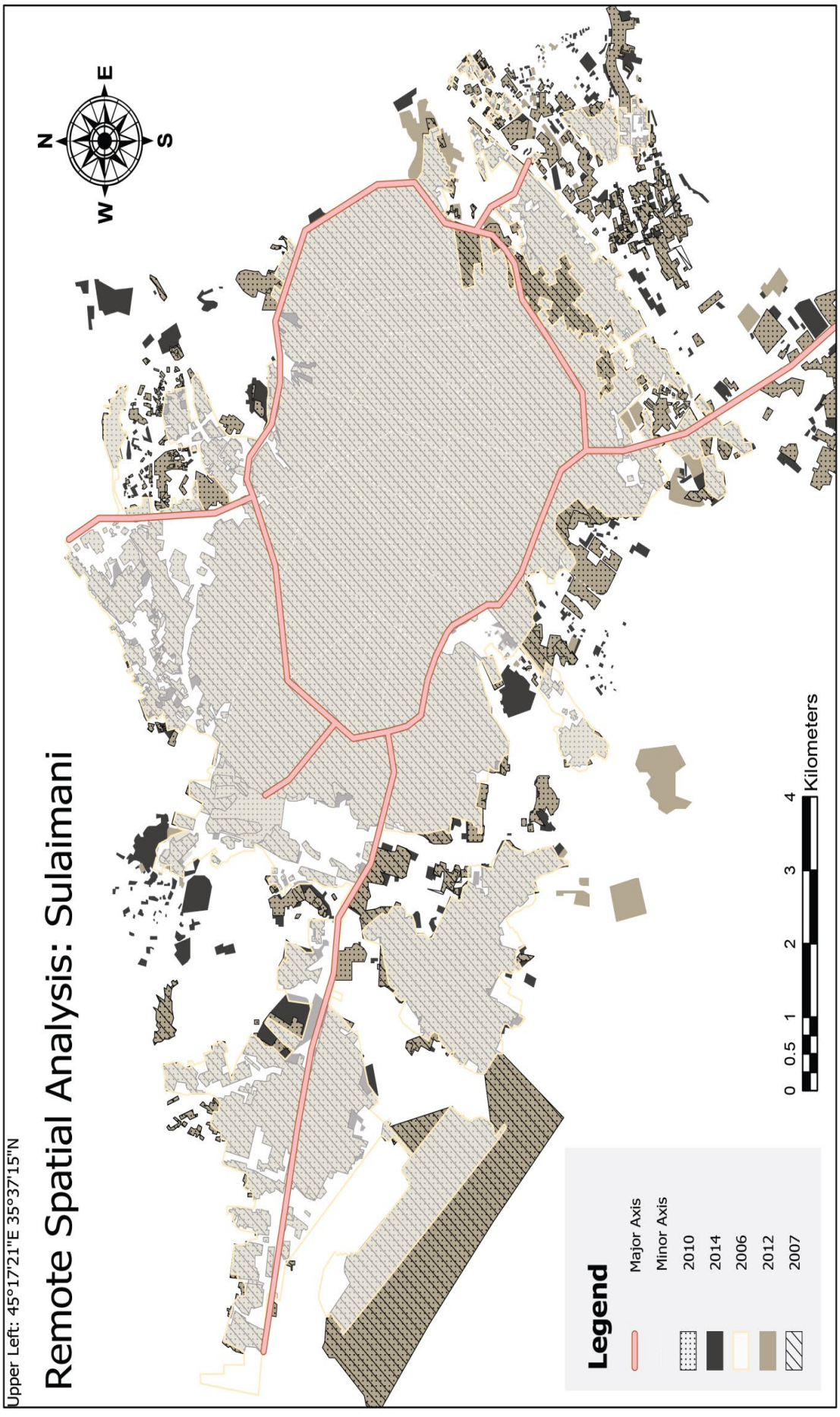

Figure 13: Remote spatial analysis of Sulaimani. [RESEARCHER].

Table 15: Georeferencing, control point coordinates [source: researcher].

Point ID	Longitude	Latitude
1	45° 25' 57″	35° 32' 11"
2	45° 26' 7"	35° 33' 21"
3	45° 23' 26"	35° 33' 54"
4	45° 27' 43"	35° 34' 41"
5	45° 28'	35° 33' 24"
6	45° 27'	35° 32' 31"
7	45° 24' 34 "	35° 33' 2"
8	45° 23' 31"	35° 34' 22"
9	45° 23' 54"	35° 34' 47"
10	45° 23' 25"	35° 34' 56"
11	45° 25' 33"	35° 35' 4"
12	45° 26' 49"	35° 34' 50"
13	45° 27' 1"	35° 33' 52"
14	45° 24' 20"	35° 33' 48"
15	45° 24' 55"	35° 33' 39"
16	45° 26' 24"	35° 34' 13"
17	45° 26' 2"	35° 33' 36"

Table a-2: Area statistics, historical spatial analysis [source: researcher].

Phase	Period	Area (km2)	Percentage (%)
Phase i	1784	13592.3637	0.01
Phase ii	1785 - 1957	351254.3526	0.25
	*	1121911.651	0.79
	1958 - 1984	398260.1341	0.28
Phase iii	1985 - 1998	20982437.68	14.70
	1999 - 2003	29308525.65	20.53
Phase iv	2004 - 2007	28859348.25	20.21
	2008 - 2013	27401723.76	19.19
	2014 - 2018	11127804.7	7.79
	2019 - 2022	23217466.39	16.26

Table a-3: area statistics, remote analysis [source: researcher].

IMG	Area	Percentage (%)
2006	71142571.52	18.66213355
2007	67474303.13	17.69987265
2010	77485247.53	20.32594558
2012	79958027.36	20.97460568
2014	85153345.37	22.33744254

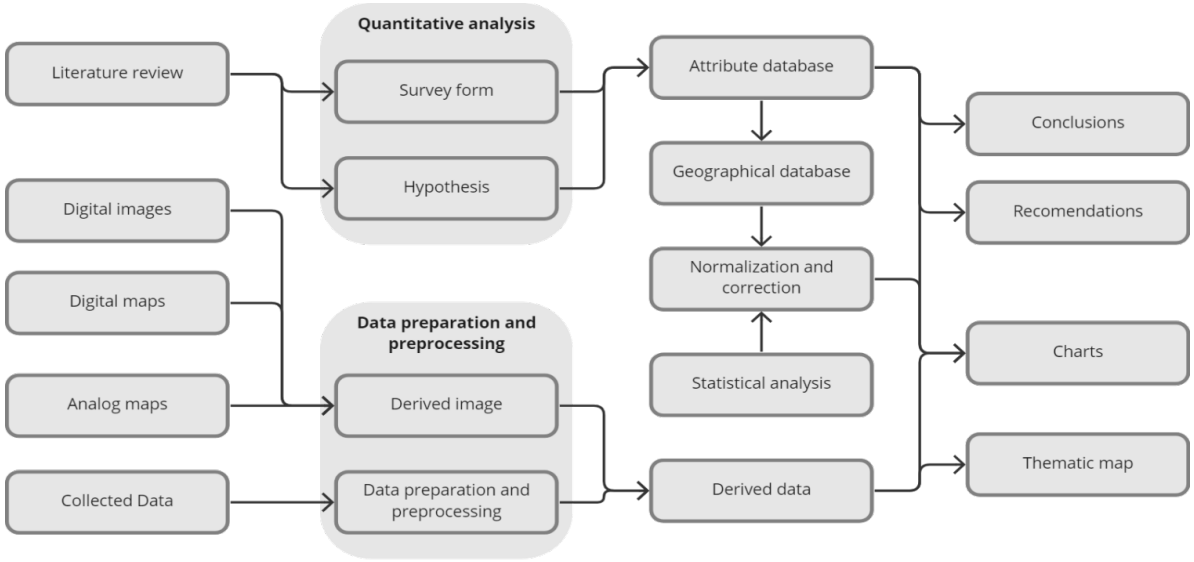

Figure 15: Study framework. [RESEARCHER].

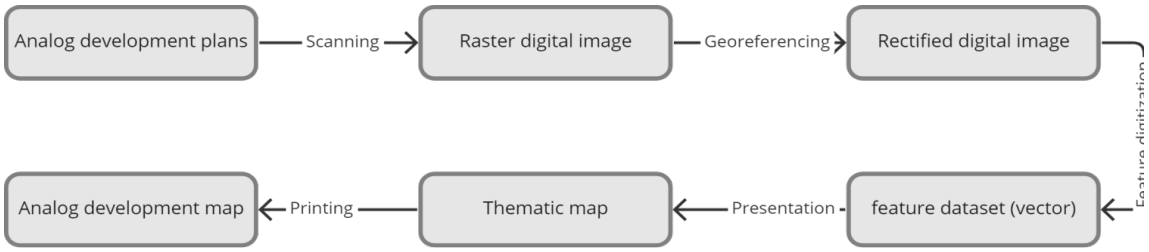

Figure 16: Processing flow: Digitization of analog images [17].

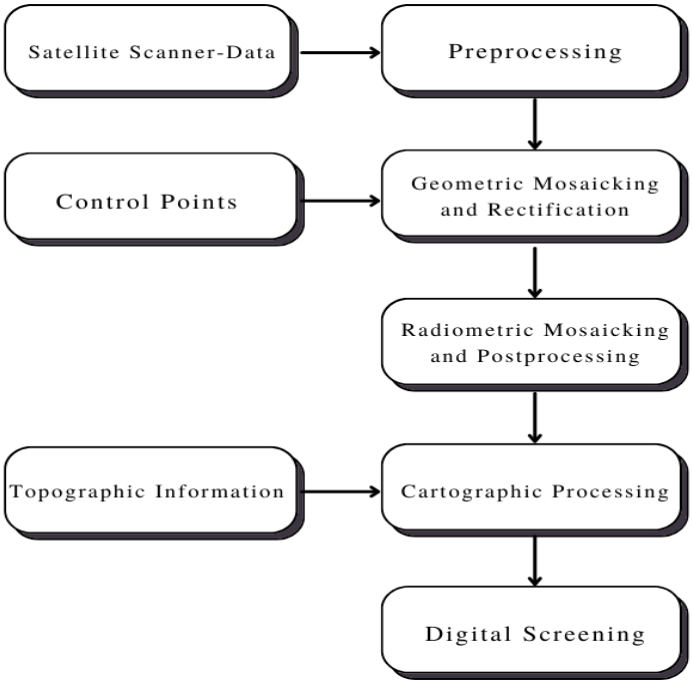

Figure 17: Processing flow: Digital image processing [17].