

MAPPING THE BEQAA VALLEY:  
BRIDGING REMOTE SENSING AND URBAN MORPHOLOGY

by

LYNN ABDOUNI

(Under the Direction of Rosanna Rivero and John F Crowley III)

ABSTRACT

This dissertation investigates how cartographic representations of the form and function of built environments can communicate the identity of peri-urban and rural towns and their strategic value in urban planning. Maps employed by urban planning efforts are typically tailored for large cities and often overlook the intricacies of small towns as human habitats, stunting their ability to develop sustainably, preserve their architectural heritage, and most importantly provide livable conditions for their growing populations. The research investigates towns in the Beqaa Valley, a stretch of agricultural landscape situated between Mount Lebanon and the Anti-Lebanon mountain ranges. The research proposes a mapping workflow of the built environment under three disciplinary methods. Carto-semiology, the study of cartographic models including maps, is deployed to synthesize how the built environment was represented in historic maps (500 A.D. – present), delineating the semantic gap between the urban condition and its cartographic representation. Urban morphology, the study of the built fabric and the processes and people shaping it, provides categorization methods of the built environment that are leveraged to distinguish between different built environment fabrics. Classification of

remote sensing data, which is the process of categorizing images including satellite imagery, generates a digital map that communicates the distribution of these different built fabrics in Beqaa towns. Outcomes of this research distill 24 unique categories of built environment fabrics that can be mapped through remote sensing data by leveraging unique indices such as brightness levels, geometric characteristics (such as rectangular fit and compactness).

INDEX WORDS: Lebanon, Beqaa, Urban morphology, Vernacular architecture, Remote sensing, Environmental planning, Urban planning, Cartography, Town planning.

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in  
Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2022

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May 2022

## DEDICATION

To

Maman chérie, fearless warrior who invites me to conquer the world.

Papa 7abibi, resident storm tamer who infuses my step with royalty and grace.

Rawad, my eternal polar star, harbor, lighthouse, and hearth.

Socrates, who commands my gravity center and vanishing point.





## ACKNOWLEDGEMENTS

While I am – proudly – the author of this dissertation, I am far from being its sole architect. Many stakeholders and supporters paved, cemented, powered up, and shaped this production.

Jack Crowley was my first vote of confidence. He saw the potential for this work miles before I could and extended me every aspect of encouragement and guidance. His omnipresent irreverent humor made the journey, even at its hardest, enjoyable. Rosanna Rivero was instrumental in exploring avenues to iterate geospatial workflows. Thanks to her, I am convinced that I can adapt to anything and everything. My appreciation goes out to my committee members: Robert Awuah-Baffour, for his no-nonsense approach that broke down the treacherous topographies of this research into logical and replicable steps. Stephen Ramos, for connecting me with fantastic opportunities and lending me prestige, thoughtfulness, and wit. Umit Yilmaz, whose love for a well-crafted product and contrarian nature fueled countless arguments in Middle Eastern crescendo, eventually setting the foundation for a rigorous product.

The companionship of Manasi Parkhi and Whitney Barr in academia, activism, and friendship was equal parts power and delight. Marguerite Madden and Deepak Mishra's enthusiasm and guidance carved me a surprising path that connects design with geospatial science. NASA DEVELOP provided a rich high-pressure experience alongside bright colleagues – Team Georgia Solar Forever. I cherish my mentors – Zoe Morris and KC Jones – and colleagues at the 2021 Future Faculty Fellowship program held at UGA's Center for Teaching and Learning. Nadya Sbaiti and Ziad Abu Rish at the Lebanon Dissertation Summer Institute unveiled a plethora of fresh scholarship and introduced me to the radical concept of the Generous Academician – it is hard to decide which of these

treasures is the most valuable. I was blessed to have the trust and support of CED colleagues to kickstart Lettus Collective and keep it running to two years. Felipe Barrantes, Saba Serkhel, Brett Conn, Whitney Barr, Manasi Parkhi, and Nora Gellona-Wagoner have been phenomenal collaborators. I am awestruck by Sonia Hirt's effortless brilliance and how she navigates intellectual uncertainty, including those of my own research, with enviable ease. Ashley Steffens hosted my first teaching rodeo at her landscape graphics class the fall of 2016 – which was the first time I realized just how much I enjoy teaching. She has been a wonderful support since then, and I hope for an opportunity to build something with her in future. Jessica Fernandez was a breath of fresh air and a sounding board for networking, angst, and plot making.

The anticipation and sense of purpose that emanated from my first academic appointment at Clemson University was on point, thanks to the entire Landscape Architecture crew but especially 'Sister Mission Point' Matt Powers who made this opportunity happen, and Lara Browning, my spunky comrade-in-teaching. It has been an absolute privilege to grow with my students both at UGA and Clemson and watch them become agents of change, havoc, and life. While they are under the impression that I am happy by default, the truth is being with them comes with its own pool of joy – I cannot wait to see what their future holds.

My family in Lebanon, Argentina, and Brazil is a fortress of support and cheer. My sister and bestie-in-chief May (Cushmush) who would patiently deconstruct my stream of half-baked jargon upon demand and reciprocate with copious helpings of admiration – leaving me no choice to fail. My baby sister Ayah's (BadaAyah) steady driving wheel and vivacious chatter put a spring in my summer data collection.

WhatsApp notes from Dina Dergham, Sarah Jaroush, Jida Mahayni, Laial Massud, my parents, and all my tias and tios never failed to heal, encourage, and restore pieces of me that longed to be with them.

My better half Rawad Saleh's unyielding belief that I will excel regardless of what and where has always grounded me, but with the last few years, it has become the bedrock of my constitution. With his keen eye and constructive comments, he served as my sixth (and favorite) committee member. Our home is an oasis protected by his patience, deep respect for dinner time, and constant humming of 1990's commercial ads. Socrates is the Mostest a parent could ever dream of. His intellectual prowess, charm, and hunger for life brought all forms and shades of happiness and pride.

Our family and I were extremely lucky to find our community and streets reigned by kids of Watkinsville GA, which was facilitated by Pamela Jessurum's enthusiasm and impeccable knowledge of metro-Athens. I especially cherish the comfort I found in Nandita Sridhar's ineffable friendship. The last year of this journey has compelled me to operate in beast mode, which I could not have done without the support and amicable taunting of the Crossfit Oconee community.

Lastly, financial and professional support from the American Planning Association's International division, the UGA Graduate School, The American Association of Geographers, the College of Environment and Design, and NASA DEVELOP made data collections and conference presentations possible, which my research could not have proceeded without. My gratitude to the National Remote Sensing Center in Lebanon, Gicome Engineers, Khatib and Alami, and GIS/Transport ltd for sharing data about Lebanon and the Beqaa with me.

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## INTRODUCTION

This dissertation investigates the semantic gap between the built environment and its cartographic representation and proposes a mapping workflow that overcomes this gap tailored for regional planning and urban design of towns and villages.

Urban and regional planning disciplines typically converge their research and professional efforts towards the city, to examine its internal economic, financial, ecological, and social complexities (Batty, 1994; Cervero, 2017; Richard T T Forman, 2014; Lynch, 1990; Mumford, 1961) and also to expand the narrative of the city as a region-maker (Duany et al., 2010; Geddes, 1950; Jones et al., 2015; Kasarda, 2011; Silver, 2008). The gravitational force of the city in is well justified, especially with the projected continuous increase in urban populations in the foreseeable (The World Bank, 2018). In this tide converging in the city, towns and villages are often planned or studied in the context of their relationship to the city or simply overlooked.

Towns and villages have their own strategic value as human habitats that shape their regional context (R T T Forman, 2019), governance organisms and processes that are distinct in their own right (Marohn Jr, 2019), and socio-economic opportunities and limitations that are verily different from those of cities (Hamdouch et al., 2017). In addressing questions of urban growth, sustainability, heritage preservation, and quality of life, considering towns and villages as a human habitat beyond the context of the city is necessary to expand urban planning's ability to articulate issues and provide solutions equitably to city and non-city dwellers.

A significant hurdle that prevents the nucleation of town and village-centric knowledge is the lack of adequate spatial data pertaining to the built environment, which can be generated through interdisciplinary methodologies connecting urban studies to cartography (the art and science of producing and analyzing maps) and geospatial science (collection, presentation, and analysis of geographic information to understand relationships of people and place). This gap –lack of spatial data – is especially noticeable in the disparity between city and non-city human environments in the Global South body of knowledge, due to the natural gravitation of professional, scholarly, and governmental resources towards the city but also due to the overall lack of spatial data accessible to the public. This research addresses this gap by proposing a mapping workflow that leverages the physical characteristics of the built environment in towns and villages and remote sensing analysis technologies to create knowledge that can serve town and regional planning and research tailored to the specificities of the built environment.

The research focuses on towns and villages in the Beqaa Valley, Lebanon. The Beqaa valley refers to the landscape separating Lebanon's two mountainous ranges (Mount Lebanon and Anti Lebanon). The temperate and arid climate of the Beqaa and abundance of water sources historically created an ideal environment for agriculture. Aside from its largest two cities – Baalbeck and Zahlé – the Beqaa is largely a constellation of villages and mid-sized towns that nucleated during the Ottoman Empire interweaving with agricultural plots as they witnessed incremental growth after the Beirut-Damascus rail line was established in 1891, intensified after the rise in personal car ownership, towards the 1950s. The Beirut-Damascus road, the shortest path that

connects the Lebanese to the Syrian capital, cuts through the Beqaa and directs commuter and commercial traffic through its towns and businesses. The built environment of the Beqaa (cities, towns, villages, and other locales such as educational campuses, industrial zones) developed in various patterns and in response to different stimuli, be it a change in governance, the construction of infrastructure, or political conflict, to name a few.

Notable historic sites in the Beqaa include the Roman temple of Jupiter in Baalbeck (established circa 60 AD), the Umayyad ruins of Anjar (650 AD), the city of Zahlé and the train stations in Dahr el Baidar, Jdita, Saadnayel, Rayyak, in addition to the educational and religious establishments constructed during the French Mandate and French influence.

Embarking on an interdisciplinary study in understudied regions requires the elucidation of underpinning disciplinary watersheds and terminological overlaps, described in the following few paragraphs.

**Land Cover Land Use Maps:** Land Cover Land Use (LCLU) maps are a form of spatial data highly utilized to inform regional urban planning research and policy as well as environmental planning, forestry, ecology, transportation planning, and disaster mitigation. LCLU maps are complemented with other data such as population, transportation, zoning to decode the multiplicities and complexities of urban dynamics and generate forecasts for upcoming changes. LCLU maps are generated by relying on classification systems. Classification systems are the sum of classes or categories used to interpret imagery, often created as a hierarchical system ranging from coarse to detailed (see description of ‘classes’ below). The level and nature of detail of LCLU maps are driven by scale and the purpose of the map. Examples of LCLU classification systems

include the International Geosphere-Biosphere Program IGBP Land Cover Classification System (Loveland et al., 1999), the U.S. Department of the Interior Fish & Wildlife Service Classification of Wetlands and Deepwater Habitats (Wetlands Subcommittee, 2013), the U.S. Geological Survey Land-Use/Land-Cover Classification System (J. R. Anderson, 1976), the U.S. National Vegetation and Classification System and the COoRdination of INformation on the Environment (CORINE) published in 1985 to systemize land use and land cover mapping in the European Continent (Kosztra et al., 2017). Recent efforts in producing LCLU maps are increasingly shaped by the need to map overlooked built environments such as informal settlements (Kohli et al., 2016; Kuffer et al., 2020), an urgency is closing the semantic gap between local knowledge of the built environment and the knowledge communicated by LCLU maps, and the need for mapping processes that lend themselves to frequent updating, exemplified in ESRI's latest global Land Cover Map (*Esri 2020 Land Cover - Overview*, n.d.). This research contributes to this growing frontier by proposing a mapping workflow that addresses overlooked built environments by leveraging local knowledge and adopting a LCLU workflow that is affordable and fast.

**Classes:** The information communicated by LCLU maps is typically presented in classes, or categories that describe the land. The term 'class' is used in both the second and third article. In the case of article 02, classes are categories or typologies distilled by urban morphological research such as historic neighborhoods, industrial complexes, or functional mix fabrics. In article 03, classification system used in geospatial analysis is the information category that describes an image object. An image object in is the footprint of a building or set of buildings, an agricultural plot, a waterbody, or vegetated

landscape visible in satellite imagery. The classes in this case are hierarchical, going from coarse (e.g. class 01 is Built Environment), to detailed. As a subset of class 01, class 02 includes facilities, developments, neighborhoods etc. and class 04 includes Public parks, hospitals, villas, refugee settlements etc. The research develops the set of classes using urban morphology, that can be transferred to geospatial analysis.

**Vernacular and Informal morphologies:** The ‘vernacular’ built fabric can be defined as the built habitat that is constructed without the intervention of a trained architect or specialist designer (Glassie, 1990; Paul Oliver, 2007), and the ‘informal’ built fabric typically considered as a built environment designed and constructed without authorization from the state (Roy & AlSayyad, 2004). Most of the built environment in the Beqaa was constructed within a laissez-faire framework, where the architect, whenever involved, does not supersede the desire and intent of the dweller or building owner . While buildings are expected to conform to a specific set of from-based codes (مكتبة زين الحقوقية والأدبية, 2017), there is little enforcement on these expectations. With these conditions, most of the built environment in the Beqaa is vernacular, and its vernacularity becomes an essential component to understand it. In some cases, the built environment is constructed outside governmental regulation altogether, thus informal. As a result, the physical aspects of the built environment and distribution of land uses reflect the processes of construction and the economic, social, and environmental conditions that shaped these processes. Deploying research methods in urban morphology that leverage site visits and primary data collection reliant on the physical manifestation of vernacularity and informality can systemize the categorization of this broad range of built environments into categories actionable for planning research, practice, and governance.

Considering vernacular and built environments as part of a continuum facilitates extrapolating research methods from informal to vernacular – and vice versa – to address the whole of the built environment as a continuous organism.

**Mapping and Counter-mapping:** With the current technological advancements in open mapping, community-based knowledge, and citizen science, integrating input from the denizens and local institutions of the multiple areas can go beyond the existing understanding of standard cartography. Non-profit and academic entities are leading the way for more pluralistic approaches to mapping. The Public Works Studio (Public Works Studio Projects, 2020) documenting issues such as environmental dangers of stone quarries owned by the political ruling class (2020, *باستديو أشغال عامة*) and the right to equitable housing by harvesting narratives from the residents of the studies towns, villages, and neighborhoods (2020, *باستديو أشغال عامة*). The Beirut Urban Lab, a research lab at the American University of Beirut investigating issues that speak to the very ontological question of how Lebanon is mapped. A very relevant example of that is rethinking the boundaries of Beirut neighborhoods and considering the new role of map production in an age of data availability (Gharbieh, 2015) and also migrating some of the atlas components from static layers towards living atlases and online databases (Beirut Urban Lab, 2020). Visualizing Palestine, a group of researchers, designers, and technologists utilizing data to advance a factual, rights-based narrative of the Palestinian-Israeli issue. Their platform, Palestine Open Maps (Palestine, 2018), shows the historic changes in Palestine, shedding light on the displacement, violence, and reconstruction of the built environment. In the case of the Beqaa, borrowing from counter-mapping practices would engage the layered geographies inherited from the Ottoman and colonial

lenses to reverse the notions of the Beqaa being an agricultural/touristic resource first, and a habitat second. Counter mapping in this case is not necessarily the critique of fallacies of the existing system, but it is an alternative examination of the decisions taken to produce cartography and the communities they represent. (Crampton & Krygier, 2006). Producing maps that reflect the intricacies of the land uses and growth patterns of the built environment can borrow from the same map-making techniques currently deployed by the National Remote Sensing Center in Lebanon. Added data points and networks of localities significant to the Beqaa communities can then institutionalize community-based or counter-mapped geographies for future regional and local regional urban and environmental planning initiatives.

### **Goals and Research Questions**

The overarching goal of this research is to synthesize a mapping process that provides for a productive portrayal of the built environment in the Beqaa valley, and that can be informative to future planning efforts. To establish the need for a mapping workflow, the first goal is to demonstrate the lack of cohesive representation of the built environment for the Beqaa valley through history by analyzing the scope and content of cartographies produced by governmental and private institutions of power from the year 150 A.D. to presently. The method deployed to conduct this analysis borrows from cartographic semiotics, which is the semiotic study of cartographic material including maps, globes, relief models, animations, and others (Schlichtmann, 2008a).

The second goal is to create a Land Cover Land Use (LCLU) classification system based on characteristics and functions of the built environment that would be essential for future regional or local urban planning initiative. Methods deployed to create this classification system are based on techniques from urban morphology. Methods in morphological study rely heavily on typologizing components of towns and villages including buildings, open spaces, street grid, density, and architectural details using site surveys (K Dovey et al., 2018; Kropf, 2017b; Vernez-Moudon, 1997).

The third goal is to propose a mapping workflow that can represent the characteristics of the built environment and provide maps that can inform future planning efforts. To achieve this goal, this research applies the classification system developed earlier, and applies it to a classification workflow using techniques in analysis of remote sensing data.

The research questions addressed in this dissertation are:

1. How was the built environment in the Beqaa Valley portrayed cartographically through history? What were the contexts surrounding the production of these cartographies and how did the lack of reliable maps of the built environment deter urban planning in the Beqaa?
2. How can the vernacular and informal built environments in the Beqaa be categorized into typologies that can inspire an alternative LCLU system specific to the region?
3. What are the data and criteria necessary to map the built, agricultural, and natural landscapes of the Beqaa valley using remote sensing data?

## **Chapter-Article Description**

The first article " The cartographic history of the Beqaa: Representations of the built, agricultural, and natural environment" investigates how the built environment in the Beqaa valley, Lebanon was represented in governmental maps and atlas documents and how these representations have influenced urban and transportation planning of towns and villages in the Beqaa valley. This article analyses six sets of cartography including material extracted from atlases produced in 1909, 1926, and 2012, diagrams extracted from a regional housing study (produced in 1958), and from a site plan for a proposed transportation infrastructure (1995).

The second article "Generating a Land Use Classification System from Urban Morphology: The Beqaa Valley, Lebanon" first distills the need for urban morphological research in investigating vernacular and informal environments, which comprise a high portion of the Beqaa's built fabric. The article synthesizes a 5-step analysis workflow inspired by urban morphology (Reconnaissance, Initial Analysis, Data Collection, Analysis, and Interpretation/Operationalization) and applies this workflow to towns and villages in the Beqaa. Results from each step of the workflow are illustrated. Results from this study demonstrate that identifiable physical markers can be categorized using research methods in urban morphology to generate a distinct classification set that would inform an alternative LCLU system.

The third article applies the LCLU system distilled in the second article to classify remote sensing data of the Beqaa Valley into an LCLU map. The workflow in article 03 complements Very High Resolution PlanetScope Multispectral satellite data and ancillary datasets with ground truthing information to overcome the semantic gap – the difference

between the character of the built environment and its map – in producing meaningful regional maps. Results show a relatively high level of accuracy for distinction between built, natural, and agricultural landscapes (72%), with a lower – but still promising accuracy level for distinction between different types of the built environment (56%).

**ARTICLE 01: THE CARTOGRAPHIC HISTORY OF THE BEQAA:  
REPRESENTATIONS OF THE BUILT, AGRICULTURAL, AND  
NATURAL ENVIRONMENT<sup>1</sup>**

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<sup>1</sup> Lynn Abdouni, *Journal of Urban Planning History*, to be submitted.

## **Abstract**

This paper investigates how the built environment in the Beqaa valley, Lebanon was represented in governmental maps and atlas documents and how these representations have influenced urban and transportation planning in the valley. A presentation of the various cartographic expressions used to map the Beqaa valley dating from the late Ottoman Empire to the recent maps (1900 – 2005) explores how the valley was crafted as agricultural land, as natural landscapes and as a transportation corridor. This paper argues that any land planning in the Beqaa valley was conducted under two main purviews: to leverage its economic productivity, and to preserve value of its natural landscapes. Disregard to the nature of its urban fabric limited the Beqaa communities' ability to develop as a cohesive urban environment. This paper investigates the semiology of cartographies (cartosemiology) depicting the Beqaa Valley, specifically those pertaining to the components of the map. This article also contextualizes it in its planning history to articulate how and why the Beqaa Valley was mapped, and how maps of the Beqaa were used to reflect or inform regional planning efforts.

## **Chapter Map**

The introduction describes the role of cartosemiology of, and critical junctures in the history of the Beqaa valley that helped shape how the Beqaa appears. Methods and selected cartography delve into the cartosemiotic elements that are considered for the analysis and describe into the material selected for this research. Results describe trend in how the Beqaa was characterized through cartographic history and interpret how this has impacted the planning for its built environment. The discussion summarizes findings and

contextualizes how the production of the map can be transformed with the rising tide of citizen-led mapping and counter-mapping.

## **1. Introduction**

Benedict Anderson (1983) enumerates three institutions of power essential for colonial powers to construct, delineate, and shape their areas of dominion: the census, the map, and the museum. In the book introducing imagined communities and the idea of nationalism, Anderson gracefully leaves space for his readers to refine or reposition the arguments he created in his ‘census, map, museum’ chapter, written specifically for the context of South East Asia (B. R. O. (Benedict R. O. Anderson, 2006). Maps and mapping have held a long-standing importance to geographers but also other disciplines in the scientific (geology, surveying, hydrology) and social sciences (urban studies, anthropology, art history, literature). The study of cartographic material in its historic context, specifically its urban and environmental historical context, can shed light on the how the region was perceived and shaped. Indeed, cartography is a potent political vehicle for implementing spatial authority in the service of the power that wishes to assert or expand its dominion. Maps were historically useful to the state, enabling functions such as successful military sieges (Tibbetts, 1987b), justification of military actions, and redrawn political boundaries (Monmonier, 1991).

The map as an instrument to represent, inform, narrate, and guide does not solely rely on the quantity and precision of the data that it represents, but also on how it is represented (Rankin, 2016). The graphic structure of the map and the organization of symbols and text is an element as – if not more – critical in crafting the narrative and the impact of the map. For this reason, cartography, described as the science and art of

displaying information on a map, remains a significant actor in the production of maps today, to curate, prioritize, and abstract data to enhance their communicability but also as a research lens to understand historic changes within a landscape.

The emergence of new capacities in digital mapping have increased the significance of map making even further (Pickles, 2012). Technologies such as Geospatial Information Systems (GIS), and remote sensing transported maps to new heights, spatially visualizing inordinate amounts of data covering political, social, environmental, health, and economic aspects (C. Brown & Harder, 2016). Crowdsourcing technologies and Internet access also made data-collection and map-making accessible to many outside the spheres of governance and research. This leveraged the contributions of citizen science as an instrument to collect data (Escobar, 2008) and also facilitated participatory design and planning (Cooper et al., 2007; Mccaffrey, 2005).

Technology's contribution to the decentralization of map-making advanced efforts in counter-mapping. Coined by Nancy Peluso in 1995 (Peluso, 1995), counter-mapping is defined as the use of cartographic techniques to correct or contest maps and spatialies produced by the state or by powerful stakeholders (Warf, 2010). Counter-mapping is

becoming an increasingly significant tool in navigating political and societal issues around the world, including retracing indigenous land ownership, ousting forced evictions, governmental corruption, and tracing back historical injustice to advocate for priorities in urban and environmental planning (Bier, 2017; Vilaseca, 2014; Wainwright, Joel; Bryan, 2009; Willow, 2013).

## 1.1 Cartosemiotics

This study borrows analysis approaches in cartosemiotics, broadly defined as “the semiotic study of cartographic models including maps, globes, relief models, animations, and others (Schlichtmann, 2008a). “Cartosemiotics” can be described as the intersection between cartography, which is the art and science of creating maps, and semiotics, which is the study of signs and symbols, their meaning and their use. Semiotic research is applicable to most, if not all, of communication channels in society. The relationship between what was meant to be communicated, the form in which it was communicated, and how it was interpreted was expanded upon by many scholars. Of these, notable are Ferdinand de Saussure (languages and the relationship between the sign, its object, and its audience), Charles Peirce (classification of signage) Charles Morris (correlation of action, its signification, and its interpretants), Roland Barthes (rhetoric of the image, especially the advertising visual), and Umberto Eco (linguistic mechanisms) (Bankov & Cogley, 2017; Innis, 1985).

Cartosemiotics belongs to the field of applied semiotics, which explains why it does not lend itself to the abstraction of linguistics and the image to the same extent as other sub-fields of semiology (Ljungberg, 2015). Cartosemiotic research facilitates intellectual enlightenment and – more urgently- practical application, where “map makers engage in various activities of sign production: they structure the information which is to be conveyed, select and use means of expression, and (ideally) see to it that a map can be read as intended.” (Schlichtmann, 2008a). Cartosemiotics investigate map symbolism, and retrieve ideological connotations in map interpretation (Schlichtmann, 2008b), thus shedding light on the purpose of the map itself. Jacques Bertin’s foundational “La

Sémiologie Graphique” was essential in bridging semiology to cartography, for both the deconstruction of archival cartography and the effective design of cartography (Bertin, 1983). Bertin’s work proved to be useful even more than 50 years after the production of his book, and despite the rapid technological developments in cartography and map-making. However it is important to note that his pursuit to operationalize semiology in cartography was not isolated. Paul Claval’s efforts on deploying cartography as a research method (Claval & Wieber, 1969), and Sylvie Rimbert’s approach to update the tools and lexicon of cartosemiology (Rimbert, 1964) were also contributive to the conversation. Preceding the late 1960’s scholarship on semiology were the efforts of statisticians and theoreticians that shaped this connection, which are not directly relevant to the goal of this paper (Palsky, 2003). Applications of cartosemiotic research on the human environment can shed light on the history of spatial patterns (Rédei et al., 2019), place-making and commemoration of history through investigation of material and symbols (Krzyżanowska, 2016), and compare amounts of information and classifications from multiple maps to shed light on the history of urban artefacts and infrastructures (Dashpilov, 2021).

## **1.2 Case study: The Beqaa valley**

The Beqaa valley refers to the landscape separating Lebanon’s two mountainous ranges (Mount Lebanon and Anti Lebanon). The temperate and arid climate of the Beqaa and abundance of water sources in the Beqaa historically created an ideal environment for agriculture. Aside from its largest two cities – Baalbeck and Zahle – the Beqaa is largely a constellation of villages and mid-sized towns that nucleated during the Ottoman Empire and interweaved with agricultural plots as they witnessed slow growth after the

Beirut-Damascus rail line was established in 1891, and a more pronounced growth after the increased ownership of personal cars, towards the 1950s. The Beirut-Damascus road, the shortest path that connects the Lebanese to the Syrian capital, cuts through the Beqaa and directs commuter and commercial traffic through its towns and businesses. The built environment of the Beqaa (cities, towns, villages, and other locales such as educational campuses, industrial zones) developed in various patterns and in response to different stimuli, be it a change in governance, the construction of infrastructure, or political conflict, to name a few. A few notable historic sites in the Beqaa include the Roman temple of Jupiter in Baalbeck (established circa 60 AD), the Umayyad ruins of Anjar (650 AD), the city of Zahlé and the train stations in Dahr el Baidar, Jdita, Saadnayel, Rayyak, in addition to the educational and religious establishments constructed during the French Mandate. Another notable aspect of the Beqaa is that it was not always considered Lebanese territory. The current boundary separating Syria and Lebanon was drawn by the French Mandate with input from local Lebanese stakeholders during the 1920's. Thus is it important to consider cartographies for Lebanon and Syria.

## **2. Materials and Methods**

Jacques Bertin defines two key elements in studying maps: the invariant and components. The invariant is defined as the “invariable common ground”, which is the main topic or subject portrayed in the map whereas the components are a finite set of information classes communicated on the topic of this invariant (Bertin, 1983). The invariant and the components can be deciphered through the map graphic itself and also by the arrangement of titles and legends that support or contextualize the cartographic

material. Along these lines, the maps considered for this analysis were either extracted from atlases that depict the entire region, or maps created in the intent of urban or transportation planning. Atlases typically show an overview of the region or country and emphasize the role of different landscapes in the organization of these regions. This in turn yields a snapshot of the hierarchy of a region or a country. This would be useful to characterize the perceived role of the Beqaa in the context of Lebanon and Syria.

Maps produced for the intent of regional urban planning are necessary to locate the origin of the representation of the built environment in the Beqaa Valley and its context. Transportation maps, as the analysis below further details, was also deemed relevant due to its attention to how it connects to the built environment. Along the lines of Bertin's cartosemiotic analysis, (Bertin, 1983) the following cartographic elements are considered in the analysis of the cartographic material:

1. Components, which conceptually in this case are interchangeable with either classes or objects. In this study, the number and order of components (or number of classes) is observed to demonstrate the extent of detail in the map and the length of components (number of sub-classes) denotes the degree to which each component was considered.
2. The text in the Atlas or the planning reports are used to further interpret the maps and contextualize further through the historic main events that shaped the image of the Beqaa valley.
3. When present, wording of titles and legends. The titles and legends are a can indicate the focal elements of the map, as well as ideological and practical motivations – the invariant of interest– of the author.

It is important to note that cartographic analyses – and in this case cartosemiotics – are also applicable to GIS data, specifically if these data were used to create a mixed atlas (combination of maps, data tables and interpretative text), because the corpus of an Atlas addresses how the data are represented and is usually accompanied with context on the main topics emphasized and in some cases is explicit in the narrative it is representing.

Cartographic material selected for this study include atlases and maps produced to either document or inform regional planning in Lebanon. The geographic scope of the material had to include the Beqaa valley and documented city locations, land cover, and land use when available. This limited the range of material significantly, as the Beqaa was seldom represented to great detail, as opposed to the coastal cities which were documented repeatedly due to their centrality. The material selected included Atlases and maps produced for regional planning purposes. Atlases are typically comprehensive with maps accompanied with context and analysis, which would make the content useful in the quest of tracing how the Beqaa was perceived in relation to Lebanon. Regional planning maps typically assess of the built fabric in the intent to develop the region. The time range considered spans from the end of the Ottoman empire to the latest atlas produced in 2016. This is not an exhaustive list, limited by the ability to access digitized or catalogued maps from educational and archival institutions. There is a need for extensive archival visits that would be dedicated for extracting material specific to the Beqaa and its cities and towns. Cartographic material and site plans that could be considered in the future include: site surveys conducted by the Jesuit convent in the Beqaa during their early establishment of the wine industry in the Beqaa, during the 1800's (Saleh, 2013),

site plans considering historic ruins and their environs (Tannous, 2020), and campus maps of educational institutions such as the American University of Beirut's campus in Hosh Sned (Sayah, 1988).

Below (Table 01) is a list of material considered in this article:

<b>Name</b>	<b>Year of Production</b>	<b>Authors</b>	<b>Scope</b>
World Maps	500 – 1500	Ptolemy, adapted	The ambition for these world maps was to document as much of the world as possible. A few items were limited to the present Lebanese and into Syria. This shed light on how the Beqaa Valley was perceived at the time. Adaptations by Veronese (1200) and Jacob D'angelo (1467).
Suriah va Beirut Vilayetler	1909	Mahomet Rushtu, & Mahomet Eshref	This atlas documents Syria and Lebanon in the end of the Ottoman Era (1890s), which is the closest depiction of the organization of territories and boundaries as well as documentation of city/town locations as well as natural resources.
Atlas Economique du Liban et la Syrie	1923	Zadig Khanzadian	This atlas documents French Mandate Lebanon and Syria and explicitly situates both countries as lands in need of development and as oportunities. Detailed depiction of agricultural and industrial landscapes.
The Plan for Lebanon	1958	Constantinos Doxiadis	These diagrams and photos were produced by Doxiadis, a Greek town planner tasked with conceiving a regional plan for land and urban management in Lebanon. Doxiadis is also known as the founder of Ekistics, the science of human settlements.
Rail and Highway Maps	1970-2005	Khatib and Alami, Gicome (engineering firms), Lebanon Railway Authority	These plans considered show the proposed and built road and rail track alignments. The rail plans are also accompanied with photos of the rail stations in their urban context, which helps shed light on the Beqaa Valley's urban environment.
Atlas Lebanon	2012, 2016	Center for National Remote Sensing	This collaborative effort documents the economic, societal, built, natural, and refugee environments in Lebanon. It is accompanied with analysis text that reflect policy and ideologies in urban planning.

Military maps and geological maps were not considered for this study, as they did not offer any additional information on the condition of the built environment in the Beqaa. The analysis aimed to answer three questions for each map/atlas: “what was the purpose of this document? How was the built environment in the Beqaa Valley represented? How did it reflect its historic context, specifically on issues of urban planning and urbanization?”

In the spirit of consistency, the analysis of these material proceeds in the following fashion:

1. Maps are described in the historical context where they were produced, with particular attention to their applications in urban and environmental planning.
2. Semiotics of the map are described, with focus on the components (number, length, symbol type) that represents the Beqaa valley, and the titles and legends.
3. The main points of the map vis-à-vis the representation of the Beqaa’s built environment are summarized and interpreted.

### **3. Results**

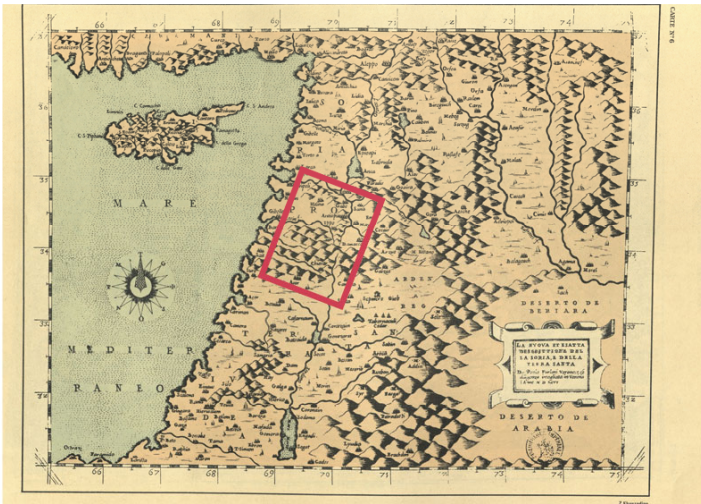
The Results sections first describe the findings following the outline of these three points, and trends in these findings are then summarized.

### 3.1 Findings and Their Historic Context

#### 3.1.1 Syria and Lebanon 150 – 1500

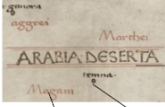


Ptolemy, adapted by D'Angelo



Ptolemy, adapted by Veronese  
Source: Khanzadian 1926

 Approximate location of the Beqa

 Region  
City/Town  
Uncertain  
Waterways  
Political boundaries  
Flat terrain  
Mountainous terrain

 Mountainous terrain  
Flat terrain, potentially vegetated  
Desert  
Waterway  
Sea  
City  
The New and Exact Description of Syria and of the Holy Land  
Author Name  
North Arrow

Figure 1.1: Ptolemy maps by D'Angelo and Veronese

The Roman Empire's conquests represented Lebanon and Syria by the *Notitia Dignitatum*, which reflected the administrative organizations of their dominion, which depicted regional maps and decorated portraits of Palestine, Syria, Armenia among the many other provinces under the Roman rule. Claudius Ptolemy, a Roman mathematician and geographer (in addition to other scholarly pursuits) who resided in Egypt and produced a generous number of maps representing the Mediterranean basin produced the earliest maps of Syria and Lebanon circa 150 A.D.

The Islamic civilization contributed significantly to cartographic sciences, specifically through celestial and cosmological techniques in mapping and measurement of land surfaces. Philosophers and mathematicians such as Al-Khawarizmi, Al-Zarqali, Ibn Hawqal, Al-Idrisi and the Balkhi school of Geography produced mathematical and astronomical charts to measure and document landscapes (geodesy) (Thrower, 1996), and these tools were rarely developed as their own discipline – there was no early Arabic equivalent for the term 'map', and cartographic issues were not perceived in a silo, but rather as natural parts of a wider intellectual curriculum (Karamustafa, 1987). As of presently, there are not many recorded practical applications to these theories, and it is evident that Islamic maps were more outward than inward looking: Maps of the world were produced in relative abundance, and material to either support or document military sieges were ripe with details pertaining to coasts, waterways, and topography. This material built upon or interacted with work produced by Greek geographers, which could be described as scholarly discourse on the science of cartography.

Pertaining to Lebanon and Syria are the *Book of Travels and Kingdoms* (*Kitab al Masalik wal Mamalik*/ كتاب المسالك والممالك) produced in the 9<sup>th</sup> century A.D. and *Book of*

Picture of the Earth (Kitab surat el Ard / كتاب صورة الأرض), along the body of work produced by the Balkhi school of Geographers. The book of travels and kingdoms documented the connections between Asia, Africa, and Europe and the earliest travel routes connecting the inner territories to the shores of the Mediterranean and the Arab/Persian Gulf, whereas The Picture of the Earth portrayed the Mediterranean basin in more detail. While the level of detail in Islamic cartography is not necessarily generous, it does give insight into influences and priorities in cartography (Tibbetts, 1987a), and it reflects the degree to which geographers from the 9<sup>th</sup> century A.D. to the 12<sup>th</sup> century A.D. mainly mapped Syria and Lebanon – as perceived in travels and trade routes – in their regional and global context, and little was produced to record the urban condition of this region.

Considered in this paper are adaptations of Ptolemy's work from 200 AD through the early 1500's mostly by European geographers such as Agathodaimon, Villadest, Solinus, Valsequa and Veronèse. These maps were largely regional in their scope, with emphasis on the water-adjacent landscapes and larger cities, which today can only be considered basemaps due to the level of information they can communicate. However, they shed light on how the Beqaa was perceived or indeed was experienced. In this time scope, production of maps was scarce. Components for these maps included the Mediterranean Sea, the coastal line, rivers, some political boundaries and city locations. D'angelo's adaptation includes political boundaries separating Palestine, Jordan, and Syria whereas Veronese only depicts the city location. This may be explained by the title on Veronese that reads "the new and exact description of history and the holy land and is signed by the author's name. It is possible that Syria, Palestine, and Lebanon from this

author's perspective was one stretch of holy land and boundaries did not matter. While both authors seem to agree on an approximate configuration of the coast and the number of rivers and lakes, they seem to disagree on the topography of the Beqaa. D'angelo's adaptation of Ptolemy's maps show the Mount Lebanon and anti-Lebanon mountain ranges almost at a perpendicular angle to the Mediterranean shore, whereas Veronese did not depict the valley at all. It was a series of mountainous landscapes, halting on the edges of Damascus.

There is little indication to suggest that any Beqaa human settlement was considered sufficiently significant to be mapped between the years 150 and 1500. This may be due to the Beqaa being a place of transience, especially for nomadic populations and trade caravans (Rostovtzeff, 1932), but it is also likely due to the lack of agreement on its topographic profile. Travelers crossing the Beqaa Between Beirut and Damascus would have to tailor their path to cross two mountainous ranges, and depending on the path, the perception of the region would differ.

### **3.1.2 Vilayet: Late Ottoman Empire Lebanon and Syria Maps - 1909**

Produced during the Ottoman Empire, the map was one of 35 in a regional atlas outlining the political geography of the empire as applicable to taxation, census and infrastructure development.

The atlas focuses on the internal political geography of the empire, with the boundaries of the provinces and regions also known as Vilayet as they were reformed in 1884 (and which remained valid in 1909 (Rushtu & Eshref, 1909). Towards the end of its reign, the Empire was dubbed 'the sick man' as its hold waned on many of its territories. The planning priorities at the time was to retrieve income and bolster economic

relationships. Of their endeavors, two were notable in shaping the Beqaa: 1) change in land tenure and 2) construction of Ottoman railways. On the change in land tenure, Lebanese denizens were able to buy the land that the Ottoman Empire had controlled.

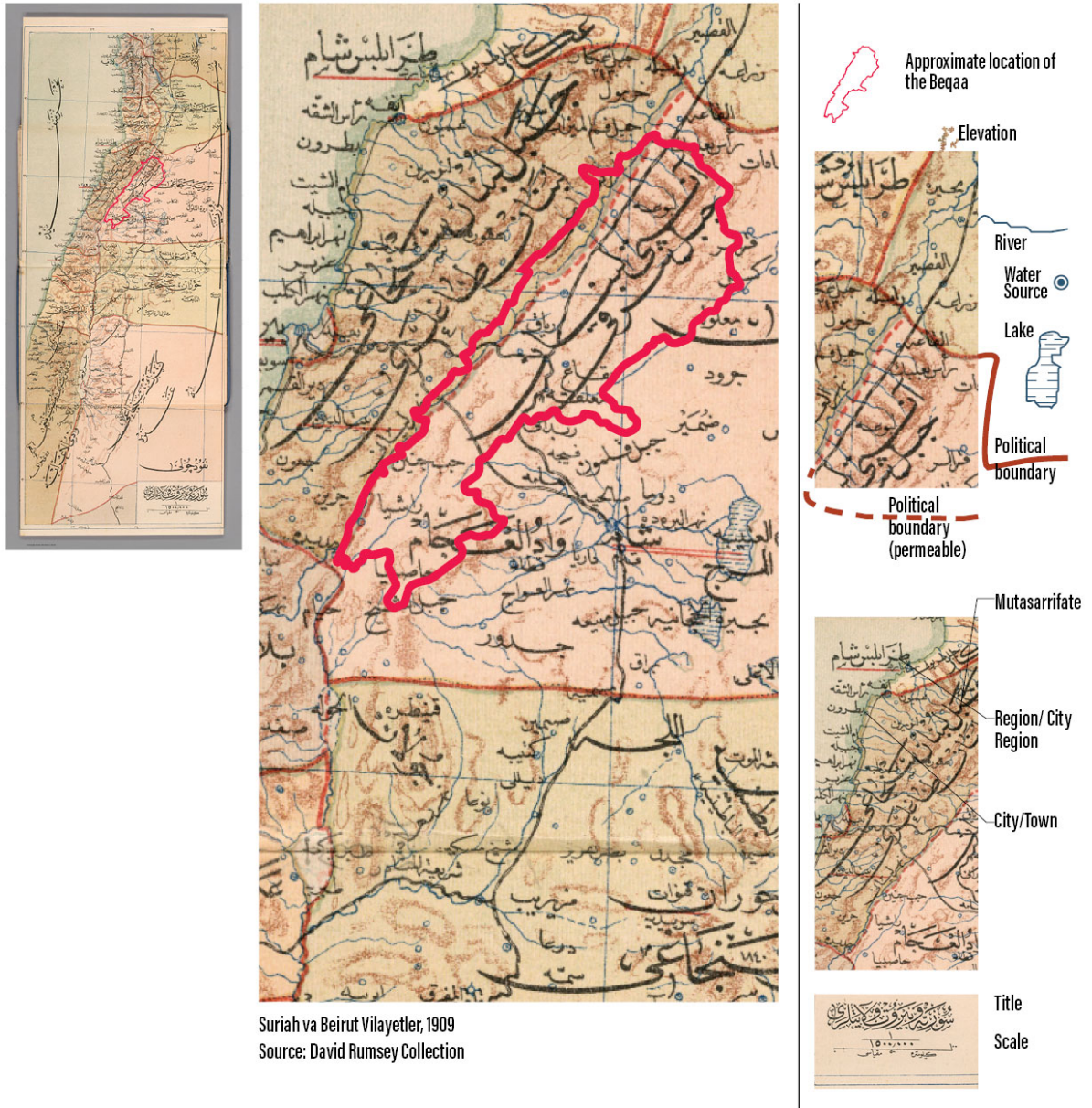


Figure 1.2: Suriah wa Beirut Villayet, 1909

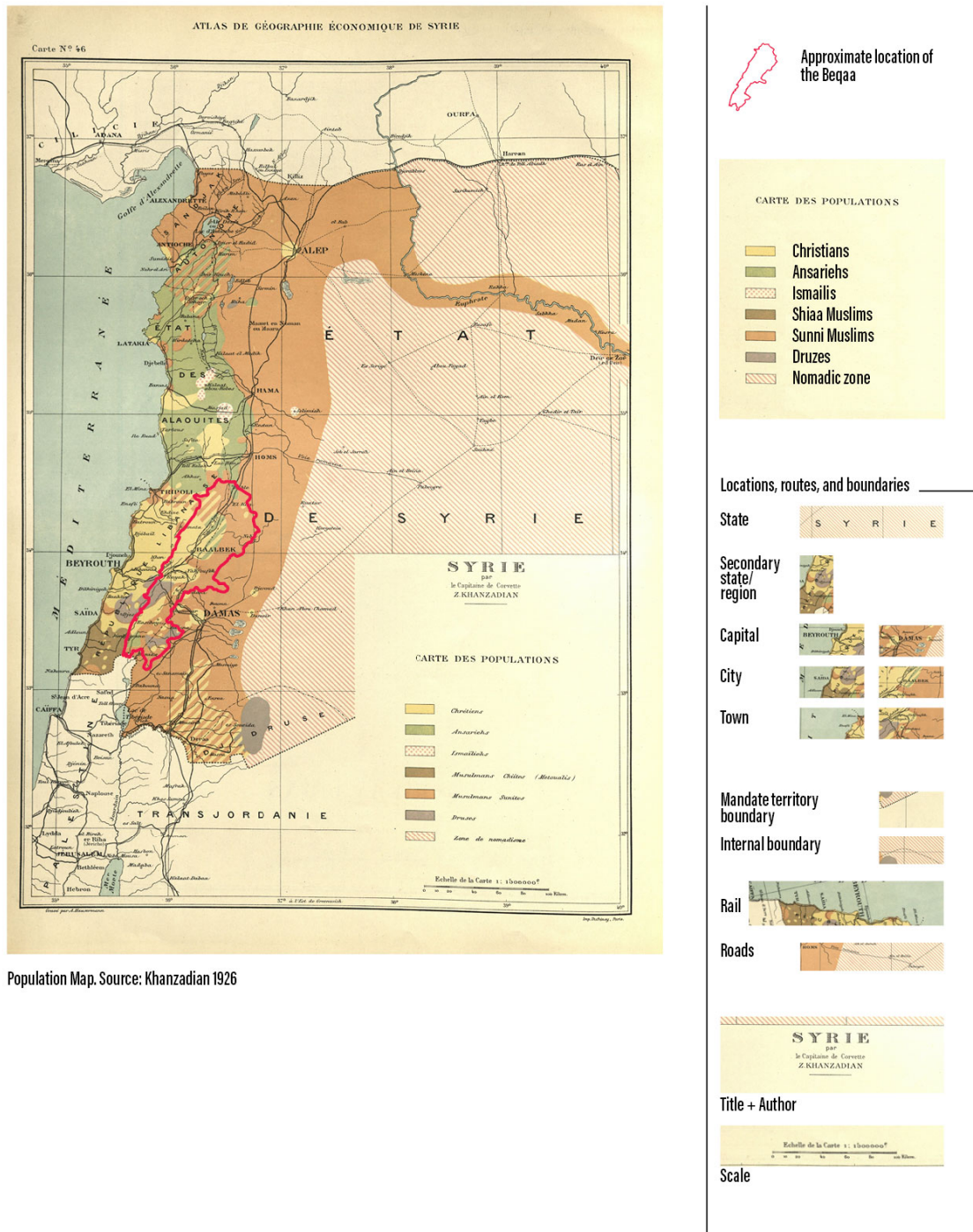
This permitted citizen of Lebanese and Syrian territories to become land owners and take control of how the land was harvested and used based on their economic needs. This set the blueprint for the Beqaa parcels: With each head of family obtaining land that is strategic for both residence (typically on slopes) and agricultural production (typically on flats), offspring of landowners would later share the inheritance by dividing the land in strips, which can be visible today in the Beqaa's landscape. On building the railways, the Ottoman Empire subcontracted these infrastructural projects to incoming stakeholders who possessed the necessary technology such as the German, Australian, and French contractors and engineers. The year 1891 marked the construction of the first line by the French company Chemins de fer Ottomans Economiques de Beyrouth-Damas-Hauran (Society of ottoman railway for Beirut-Damascus-Hauran), which as its name indicated, connected Beirut to Damascus by way of the Beqaa Valley, specifically Dahr el Baydar and Rayak (where a military airport was also later constructed) (Choueiry & Maalouf, 2013). The second line installed in Lebanon connected Rayak to Baalbek in 1902, and coastal lines were installed in subsequent years. In this atlas map, the main elements representing Beirut and Syria are political and administrative boundaries, major cities, towns, roads, railroads, rivers and mountains. At the time, the Beqaa Valley was considered Syrian territory, and Lebanon's extent included Beirut and part of today's Mount Lebanon. Lebanese government at the time was afforded special treatment by the Ottoman Empire, mainly on the grounds of religion and Beirut's relationships with French and Italian government. While most of these small-scale intricacies are not reflected in the atlas' regional maps, there are several discernable historic landmarks in the map depicting Syrian and Lebanon. The first and most obvious are the thick red lines

delineating political boundaries. While the Beqaa falls into Syrian territory, the boundary between Lebanon and Syria is dashed, which suggests permeability due to the infrastructural connection (rail). Conversely, boundaries separating the vilayet of Beirut from Beshara country (presently the Mohafaza of southern Lebanon) and Tripoli-Damascus (presently the Mohafaza of north Lebanon) are depicted continuous. The representation of the Beqaa is also noteworthy. Towns are individually indicated using dot symbols, including Rayak, Jeb Jannine, Hasbaya and others. The Beqaa is also indicated as a dot, specifically labeled “Beqaa-Maallaka”. Presently, Maallaka is used to indicate a town outside the city of Zahle. The city of Zahle is not represented on this atlas, despite being more urbanized than some of the other represented villages and towns at the time. Baalbeck as well is not depicted on the map, despite the presence of large and impressive Roman historic ruins, which indicates its age. This sheds light on the Empire’s perceived hierarchy of settlements in the Beqaa, and also demonstrates that the valley was not perceived a region but rather as a constellation of disconnected towns and cities on the outskirts of Damascus and as an economic resource, despite its clear topographic profile (a valley between two mountainous ranges). The Ottoman Empire collapsed following World War I and slowly deteriorated as colonial rule crept over the Middle East and North Africa. For Lebanon, the infrastructure for French control was already in place with the growing rail lines.

In sharp contrast to Islamic cartography, Ottoman cartography was much more prolific and was produced for more practical rather than scholarly purposes. This increase in volume of printed material was possible due to technological developments for printmaking and land measurements. It benefited from theories in geodesy and

celestial mapping established by Islamic scholars, as well as cartographic techniques in contemporary Europe. With the increased accuracy of maps and the speed at which they are produced, governmental powers – Ottoman and European alike – leveraged cartography as an instrument of staking or justifying territorial claims and disseminating political propaganda (Ben-Bassat & Ben-Artzi, 2018). In terms of content and material, the Ottoman Empire’s characterization of the territories under its control spanned beyond the locations of cities and towns and the landform at the nexus of water and land into a broader range of topics, including topography, land cover, and land use and transportation infrastructure. The urban fabric was also documented to a much greater detail, sometimes introducing illustrations from Islamic book art traditions to create composite graphics for major cities in the Ottoman Empire in the intent to craft the image of the city, or the image of the state (Ebel, 2002). The end of the Ottoman Empire is commonly demarcated with the beginning of the World War 1, but in the case of Lebanon and specifically the Beqaa, the gradual release of the Ottoman rule retreat began in the late 1880’s, where foreign contractors began building rail that connected Ottoman and non-Ottoman territory (Landau, 1971), and the Ottoman Empire sold lands to local denizens , relinquishing authority on land management (Saliba, 2004) and shifting land ownership and governance patterns.

### 3.1.3 Khanzadian's Economic Atlas and railway maps - 1926



Population Map. Source: Khanzadian 1926

Figure 1.3: Distribution of populations map, Khanzadian 1926.



Map of Grain Cultivation



Map of Irrigations

<p>Approximate location of the Beqaa</p>	<p>Title</p> <p>Author</p>			<p>Scale</p>
<p>Landmarks, routes, and boundaries</p>	<p>Grain legend</p>		<p>Irrigation legend</p>	
<p>State</p>				
<p>Secondary state/Region</p>				
<p>Capital</p>				
<p>City</p>				
<p>Town</p>				

Agricultural Maps. Source: Khanzadian 1926

Figure 1.4 Crop maps, Khanzadian 1926.



Map of Fruit Cultivation

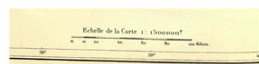


Map of Irrigations



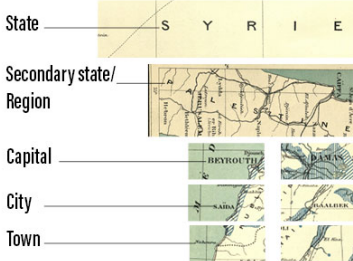
Approximate location of the Beqaa

Title  
Author



Scale

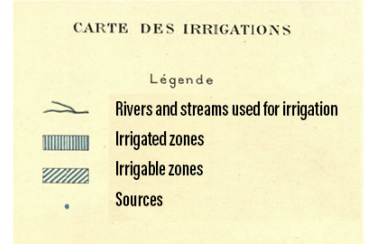
Hierarchy of locations



Fruit cultivation legend



Irrigations legend



Agricultural Maps. Source: Khanzadian 1926

Figure 1.5 Fruit cultivation maps, Khanzadian 1926.

Produced to reflect the French Mandate's interests and Lebanon's change in governance, Khanzadian's economic atlas comprehensively mapped natural resources, topography, and crop information in Lebanon and parts of Syria (Khanzadian, 1926). Lebanon's current borders were traced during the 6 years where Lebanon was known as the State of Greater Lebanon. During those 6 years, the French Mandate expanded Lebanon's borders beyond those drawn by the Ottoman Empire, to connect the coastal cities and into the Anti-Lebanon mountain ranges. These new borders moved the Beqaa from Syria to Lebanon. With Syria and Lebanon both under French mandate, the newly established Syrian-Lebanese border remained permeable enough to serve the French interests in Lebanon. It was not until the year 1943, when Lebanon became independent from the French, that these borders delineated Lebanon as a territory. During the French mandate and even after the tension precluding and preceding the 1943 independence, Lebanon maintained political and diplomatic ties with Syria. Many officials, scholars, and business people expressed their sympathy and affiliation with Syria. This affiliation is evident in Khanzadian's positionality in his atlas. The introduction clearly expresses that the historic cartographies and new maps were compiled and produced to serve French planning interests, positioning France as an ally: "France did not go to Syria as a conqueror, but rather as a liberator. Her unique goal is, while taking into account diversity of races, customs and traditions, to organize the country and to reconcile all the activities and riches [...] and to ensure competitiveness, order, peace, justice and prosperity" (Khanzadian, 1926). The atlas included a collection of historic precedents in addition to a collection of cartographic maps he had produced with associates in Paris on Syria and Lebanon. The atlas' scope is divided under four main themes. Historic

geography covers “ancient Syria” and the French presence. Physical Geography covers hydrology and soil. Natural resources covers agricultural, mines, and forest areas. Commerce and industry covers import, export, transportation routes and tourism. The atlas included a few maps on the built environment for coastal cities such as Alexandria, Beirut, Tripoli, and Damascus, but little else on other cities and towns. In Khanzadian’s atlas, the topography of the Beqaa was significantly more accurate. In terms of population, distribution of religious affiliations were depicted. Crops, natural resources, and water landscapes were depicted in great detail. The components were helpfully enunciated in the legend, showing distinction between different kinds of crops and hydrology. Color and texture was strategically used to signify overlap (observed in the grain production map, where yellow indicated cultivation of wheat and barley, and when overlaid with a black oblique hatch texture also signified corn), potential (in the hydrology map, a vertical hatch signified irrigated zones, whereas an oblique hatch signified irrigable zones), and an increased layer of specifics (in the orchard production map, thin green oblique hatch indicated general cultivation of fruits, which can overall with a thicker oblique hatch to indicate fig or stone fruits). Water sources were indicated as a blue dot, which then indicates value to where the water comes from in regional planning. Agriculture and production was also depicted with great detail, with separate layers for grain, orchard, and animal husbandry. In these layers, the Beqaa doesn’t quite emerge as a distinct place but the dynamism and its agricultural productive power is evident. In a map showing existing and suitable landscapes for growing “industrial plants” the Beqaa appeared viable for the cultivation of cotton and tobacco. This is also

evident in a map showing the religious distribution of inhabitants by location, showing the Beqaa

This sense of overlapping layers and dynamism is also visible in the religious distributions of Beqaa'I residents. Compared to the coast (mostly occupied by Christian Lebanese), and South Lebanon (majority of Shiite Muslims punctuated by a few Christian settlements), the Beqaa is portrayed with interlaced hatches and shapes of Christians, Druze, Sunno Muslims, and Ansariehs. While this characterization may not be necessarily accurate, it anchors the notion that the Beqaa is a transient region with no clear boundaries beyond the physical and topographic. Another tangential comment on this map is the number of components designating Muslim societies (Ansarieh, Sunni, Shiaaa, and Ismailis), opposing one component for Christians, despite the many sub-sects that compose the Christian societies (Greek Orthodox, Catholic, Armenian). This may be due to the positionality of Khanzadian and his allegiance to the French mandate, which is cultivated through Christian communities and institutions (universities, churches). This then positions the Muslim communities to the author as the "other", in cartography, the other is documented using the "outward gaze", which is manifested with more detail. The mapped railways in the Atlas distinguish between Syrian and French rail lines. Syrian rail lines were under Ottoman control until their withdrawal, whereas French rail lines were developed under French purview from the beginning. The lines connecting Beirut to Damascus were largely French. Rail lines and infrastructures are represented in standardized symbols, and there is more detailed indication on the nature of the built environment. The components (detailed in the legend) distinguish the historic landmarks (Arabian castles, enclosures, Phoenician ruins, Roman ruins, etc.). While rail stations are

not designated in the legend, they are shown as a circle with a black stroke and a clear center. The atlas did include more detailed footprints of the built environment under “Beirut and hinterlands”, “Tripoli”, and “Damascus and hinterlands”, and this indicates the hierarchy of these locations.

The Syria and Lebanon Atlas was not the only tome produced by Khanzadian. Other volumes he produced covered Turkey and parts of Europe so this interpretation of layering the economy and natural resources was not unique to Khanzadian’s (and by association the French Mandate’s) perception of Lebanon. The distinct features that are useful are the degree to which the Beqaa was represented, and the absence of any representation of the built environment, despite the rail stations crossing the towns of Jdita, Saadnayel, Riyyak, and others. This meant access was feasible and the historic ruins would have provided sufficient gravity for further study. If anything, this indicates that the Beqaa was portrayed as a vague and uninhabited territory despite the existence of built environment landmarks. This can be construed as the deliberate portrayal of the Beqaa as a resource, but not as a habitat, which in a way could strip it of any strategic and political power.

Upon the full realization of British and French colonialism in the Middle East, a new imagined future of the Middle East came to the forefront. This imagined future of the Middle East began with dissecting the Ottoman Empire’s dominion into British and French colonial states, and in the case of Palestine, the establishment of a Jewish state. With these physical dissections, the role of the map in finalizing new boundaries was palpable, and then gained an additional function. Here, maps became a part of the process for political decision-making. While these redrawn physical boundaries were precluded

by many negotiations between the colonial powers and in some special circumstances local stakeholders, in cartographic terms, they were simply symbolized as continuous or dashed lines on a map, designating where a territory begins and where it ends, and in the same vein, where one sovereignty begins and where other end. This is not to say that upon implementation, these boundaries immediately disrupted the organization of the territories established by the Ottomans, as the concept of ‘boundary’ in itself is not absolute or set in stone. In fact, what is a decided political boundary on a map is rarely as decided as it is depicted. Quite the contrary: a boundary tends to be flexible, uncertain, and porous, especially challenged by societal and economic dynamics that break through these mapped boundaries, sometimes even disregarding them altogether (Khalidi, 1998; Mitchell, 1991). Colonial powers deployed the map primarily to document their claim to natural, strategic, military, and in some instances human resources they aim to either control or develop by 1) designating them as distinct symbols on the map; and by 2) drawing a boundary that encircles them. While deciphering the map, both as an institution of power and as a documentation tool, is helpful to understanding colonial governance of the Middle East, it is also helpful to understanding the organization of territories in the Ottoman Empire. The maps considered in this article are indeed the manifestations of the institutions of power, Ottoman, French, or Lebanese. It is important to note that the production of political changes and their cartographic representations during the mandate were also often led by local scholars, researchers and government officials who advocated for the interest of the country, but also in the interest of their own societies or communities. For example, Boulos Noujajm’s *Question du Liban*, published in 1908 stated that the *mutasarrifiyya* (the subdivision system installed by the Ottoman

Empire) is “no more than a stepping stone towards real independence, which some day would be achieved with the help of Europe”, and that was to preclude a desire for the Lebanese boundaries to include Beirut (which was not part of Lebanon), the Beqaa valley, and parts of South Lebanon (Firro, 2003). This desire was inked into mapped boundaries in the 1920’s Treaty of Sèvres. One of the main Treaty’s goals is to dissect the eastern Mediterranean basin ottoman territories into states under temporary custody of the British and the French mandates. These new boundaries, verily reflected Noujaym’s proposal of including Beirut, the Beqaa, and South Lebanon, and established the state of greater Lebanon, (Etat du Grand Liban; دولة لبنان الكبير Dawlat Lubnān al-Kabīr).

#### **3.1.4 Doxiadis’ planning visit 1957-1958**

In 1958, regional planner Costantinos Doxiadis was invited to assess Lebanon to propose housing solutions, under the National Housing Project of Lebanon. Doxiadis sequestered his site visits by Mohafaza, (Beirut, Mount Lebanon, Beqaa, South Lebanon, and North Lebanon). Doxiadis’ approach to planning was guided by ekistics, the science of human settlements, a term he had coined and developed through his career. Ekistics responds to the need for understanding, documenting, and planning for the broad range of human settlements through five principles: 1) maximization of contact with natural resources (such as water, tree cover); 2) minimization of the effort required to leverage or utilize these resources; 3) optimization of safety; and 4) optimization of the quality of the human’s relationship with the environment; and 5) achieving a balance of the previous

four principles through achieving a synthesis (Doxiadis, 1970).

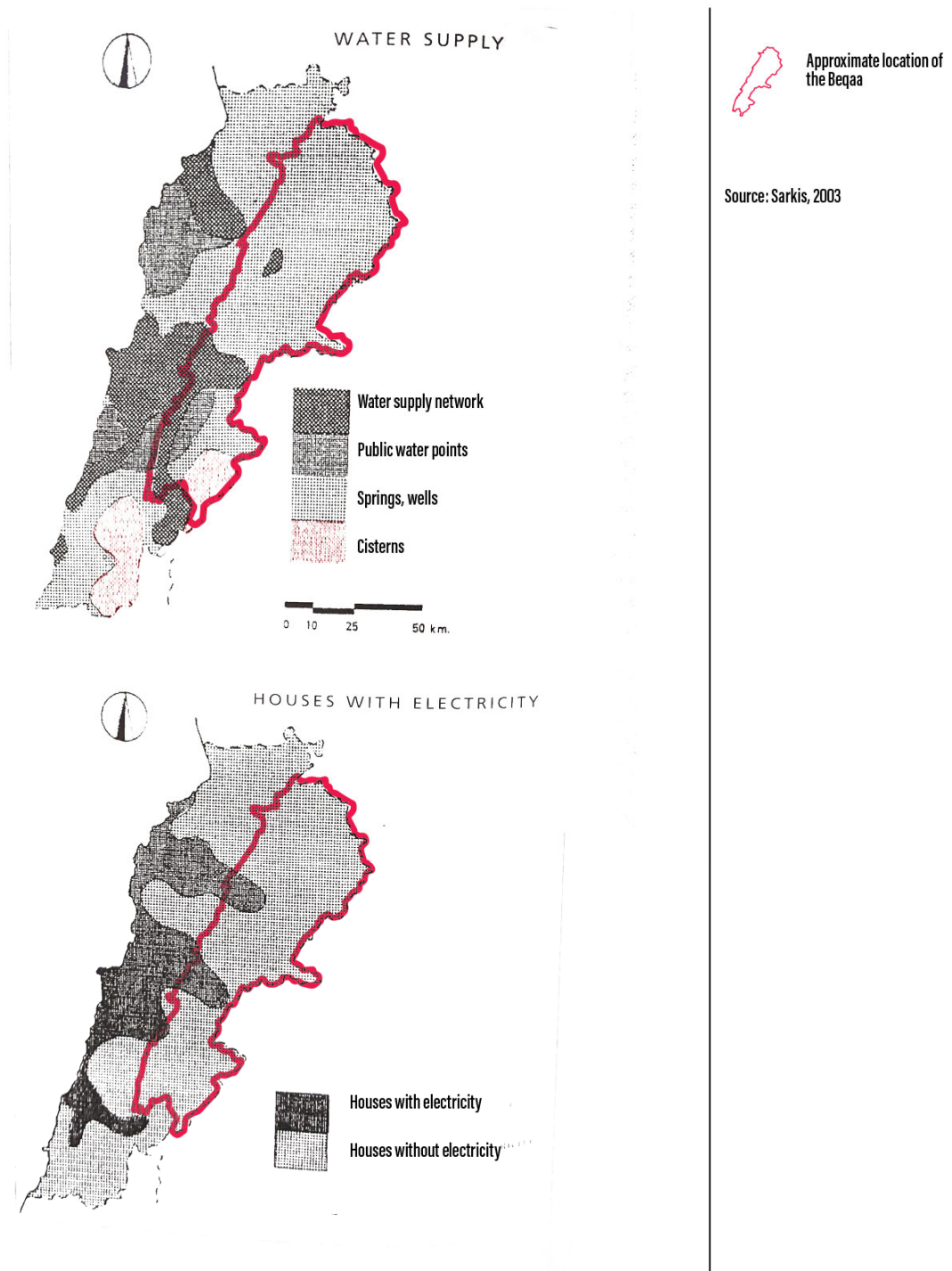
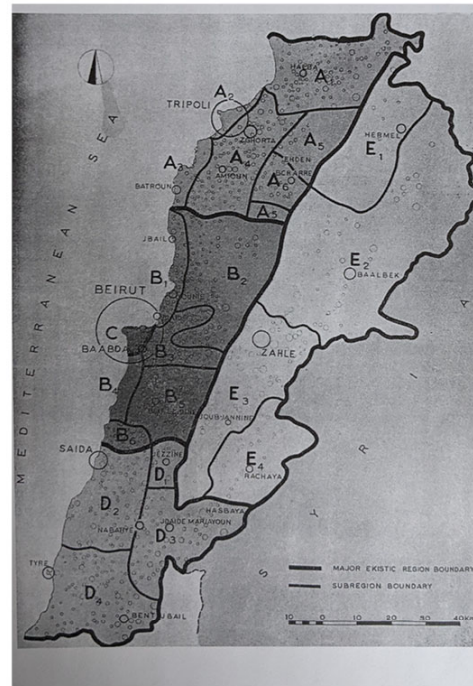


Figure 0.6 Electricity and water supply distribution in Lebanon, Doxiadis 1958.



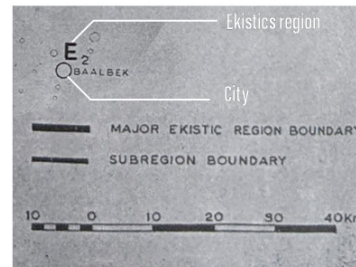
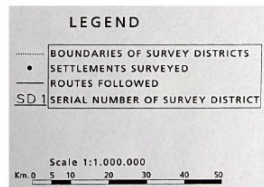
Doxiadis' survey districts in the Beqaa valley



Doxiadis' ekistics region districts in the Beqaa valley



Approximate location of the Beqaa



Source: Sarkis, 2003

Figure 0.7 Ekistics and survey districts, Doxiadis 1958.

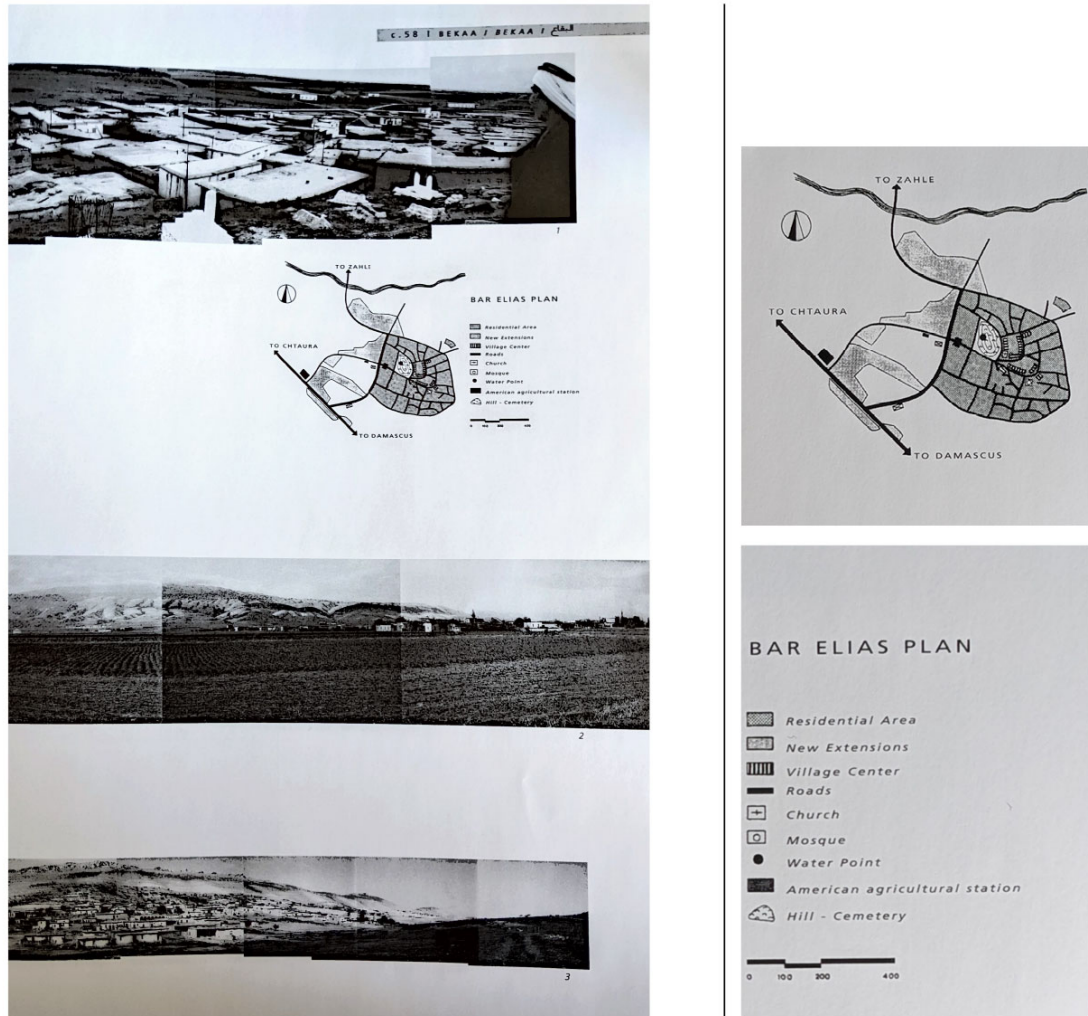
On a regional scale, Doxiadis led the first attempt at planning for the future of the Beqaa valley as a human settlement, and not as a mere repository of agricultural and natural resources. Ekistics proved to be a productive scholarly lens for planners,

engineers and architects investigating rural settlements and regional scales, especially in understanding communities and towns (Tyrwhitt, 1965), which was promising for the Beqaa. Unearthing these systemic relationships between the natural and built environment would require a prolonged timeline with ample resources, especially with the lack of population and built environment data in the Beqaa. However, the timeline was just one year, of which 6 months were allocated for the collection of photographs from 1,620 villages and towns. and the demand for information to support a plan for national housing was urgent. Doxiadis and his team relied heavily on his site visits and photographs, steering away from touristic attractions, scenic routes, and historic ruins and documenting “ugly things” (Sarkis, 2003). At the time, the Beqaa held the smallest population amongst the other Mohafazat and the largest area. Doxiadis allocated many site visits to the settlements in the Beqaa Valley, and this article considered only the plans and photographs published in Hashim Sarkis’ book “Circa 1958: Lebanon in the Pictures and Plans of Costantinos Doxiadis”.

The Beqaa chapter included photos of the built environment in the Beqaa and diagrammatic plans of Bar Elias and Kfar Zabad, which demonstrated attention to the building morphology and land uses, and contextualized the built environment within the natural and agricultural landscape.

Future research on Doxiadis’ comprehensive approach would include visiting the Doxiadis Associates archives in Greece and unearthing photos and diagrams for other towns in the Beqaa, which could shed more light on the data that informed the report that outlined the number of housing units proposed for each mohafaza, the role of each type of building in optimizing the functionality of town settlements (shops, schools, religious

places etc.), and even some plan and section elevations for proposed housing typologies (Doxiadis Associates, 1959).



Doxiadis photos and diagrams in the Beqaa Valley  
Source: Sarkis, 2003

Figure 1.8 Photos and diagrams in the Beqaa valley by Doxiadis' team, 1957.

Doxiadis Associates was invited again to prepare another report in 1997, but very little of his recommendations was actually implemented. The cartographic material produced by the team was reflective of an intent to map as much of Lebanese housing.

The surveyed locations considered the political administrative boundaries, as previously mentioned, and the ekistic regions and subregions delineated by the team had boundaries that were very similar to the mohafazat and the cazas. The settlements (towns, villages) visited were indicated using a dot. Routes that surveyors followed were also indicated on the map. The Beqaa included 6 survey districts (SD 12 through SD 17), the routes followed align with the Beirut-Damascus old road and arterial roads leading into the north eastern regions of the Beqaa (Baalbeck and Hermel), and West Beqaa (Yohmor and Rachaya). The routes followed contoured the plains and some of the slopes of the Mount Lebanon ranges. The access to electric and water resources were measured for houses and represented using a continuous texture. There were two components for electricity (access or no access), and water by source (water supply network, public water points, springs and wells, cisterns). The value of access was likely determined by settlement, and the boundaries of this access fabric was likely extrapolated from these point data collections. What is remarkable in the water map, is the absence of rivers and point data to determine the water sources, although a national map of water bodies was likely available data 30 years after the publication of Khanzadian's atlas. The team does show the water source on the town or village scale, which means that the location or natural and ecological resources in relation to the built environment were at the very least considered. Another interesting detail in the electricity map shows houses that have access to electricity in the Beqaa aligning with the Beirut-Damascus road imprint. Doxiadis' team divided the Beqaa into 4 ekistic subregions moving from north east to south west: Hermel (population of 19,924), Baalbeck (67,467), Zahle and West Beqaa (90,273), and the mountains of Rashayya (15,397), noting the importance of the Beirut-

Damascus main road the making of the Zahle-West Beqaa subregion. Based on the surveyed settlements map, the towns that have informed mapping access to electricity are located near the Beirut-Damascus road (such as Bar Elias, Qab Elias, Aanjar), but also near other arterial roads leading to Zahle, Forzol, Yaate to the northeast, and Kefraya, Jeb Jannine, Rachayya to the southwest.

Concerning the built environment, photos from Doxiadis' team were very telling in showing the built-agricultural interface and captured to some extent the character of the ordinary, normally unremarkable built environment. In the diagram documenting Bar Elias, the cemetery is shown at the heart of the settlement. There are no contour lines or any indication of elevation but the legend states "Hill-cemetery". There is a distinction between "residential area" (dotted pattern) and the "new extensions" (light solid grey) of the town, which was indicative of early growth patterns. The "village center" was also distinguished using enclosed rectangular symbols. Point locations include the mosque, church, water source, and an American agricultural station, which was likely established in the 1950's when Lebanon received technical assistance from the United States to improve their agricultural practices (Homs, 1957). panoramic views show the closely-knit fabric of one-storied buildings, framed by the mountainous range slopes and tapering off into agricultural land. Other photos captured by the team showed details on school buildings and private homes, how the rivers cross through the built environment (Anjar and Qab Elias), and factories.

### **3.1.5 Engineering Plans for the Pan-Arab Highway - 1960s – 2010s**

Transnational studies on a limited access facility (M30 / Western Iraq – Eastern Mediterranean) began in the 1950's as part of the "Arab Mashreq International Road Network" agreement with stakeholders from all 22 Arab Countries. The M30 route section, also known as the Pan-Arab Autostrad or highway, was conceptualized to connect the Beirut port to Al Rutbah Iraq, crossing through Syria. Construction of the Lebanese segment was initiated the 1960's, and much like the rail design and construction from the previous century, this infrastructural project pulled financing, design and construction firms both local and international including France, Italy, Germany, and later Arab Gulf countries and the United States. It is important to note that the rail underwent significant changes: In 1961, the rail lines became the property of the Lebanese state. Passengers decreased significantly, most likely due to an increase in personal vehicle ownership and the relative higher speed of traveling by car or by bus from Beirut to the Beqaa. Around 1976 and due to the civil war, the Beirut-Beqaa train stopped operating, and other lines gradually stopped within that same time period. In the 1990s and following the end of the civil war, efforts to reconnect Lebanon prioritized automotive infrastructures, so the railway system was never restored. There were some historic preservation efforts later to restore some of the stations but the lands where the rail line was installed was encroached upon by the growing built fabric. The impact of the rail on the organization of built environment densities in the Beqaa remains visible to date, and aligning access point to the austrostad with the previous locations for rail stations probably had a significant role in anchoring that impact. Maps to propose the most viable road alignments were produced by engineers and scientists, with detailed

attention to elevation, road alignment traffic projections, and locations for access points. Documents and maps produced naturally were naturally detailed to facilitate cost estimate studies and construction. Comparisons between different alignments were considered, assessing the return on investment and the potential for commuter and freight traffic increase (X.U.D. Dorsch et al., 1970). Studies also detailed economic impact in the early stages of design and bidding, taking into account the Beirut port and oil terminals in Tripoli (north Lebanon) and Sidon (south Lebanon), and the business the existing rail lines crossing through the Beqaa and most importantly Rayyak, that also had an airport and posed an opportunity for a dry port. In plans produced in the late 1990s through the 2010s, engineers leveraged developments in software technology and deployed programs such as AutoCAD, Geospatial Information Systems and Google Earth imagery to portray the proposed infrastructures with an increased accuracy. 3-D rendering programs were also used to simulate the driving experience on the highway. Photographs in abundance were deployed to document the construction process. These products showed the proposed infrastructure in relation to the built environment, but did not necessarily detail how the built environment was impacted or how it would change in response to the highway. This is not due to any lack of knowledge. In interviews with Engineers from Khatib and Alami (K&A) and Gicome, firms who participated in the design, stakeholder engagement, and implementation of the Pan-Arab highway, lead engineers discussed challenges emanating from their experience in this process. An engineer from K&A narrated the support local commuters expressed to the construction of the highway to reduce time spent traveling to Beirut, but also the worry expressed by the business owners on the highway diverting traffic and customers from what was, up until recently,

the main way to travel from Beirut to Damascus. He also mentioned unforeseen reactions to the new construction, including sabotage of newly installed street lights, possibly because it made some areas more accessible and visible, which doesn't agree with the activities of some community members (he meant illegal activities such as smuggling but was vague on that).



Removing debris from local waterways adjacent to the construction.

Courtesy of Khatib and Alami.



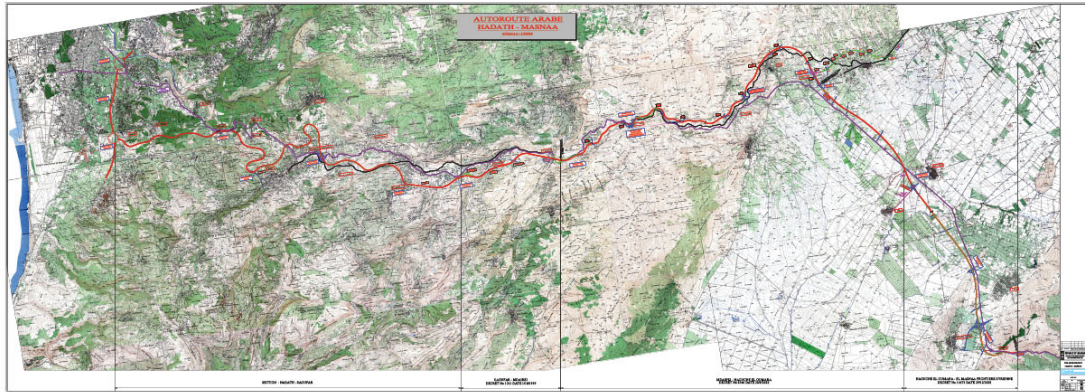
The Pan Arab Highway under construction.  
Courtesy of Khatib and Alami.

Figure 1.9: Documentation photos from the construction of the Pan-Arab Highway, 2010

Another unforeseen reaction emanated from the refugee settlements that started developing in Lebanon upon the 2011 Syrian war. Apparently crushed gravel, used

frequently in the construction of the highway, was ideal to line the floor inside refugee shelter tents, providing drainage especially for refugees who poured a concrete foundation, which is why he suspects refugees looted gravel from construction sites. Representatives from the Center of Development and Reconstruction (CDR), established in 1977 and essential to the post-civil war construction efforts cited issues with land acquisition in the central and west Beqaa, due to fluctuations in land cost and general resistance from land owners seeking to maximize compensation for the land they had to forgo for this highway. Although these interactions are not necessarily representable on the national scale, they are signs of a lack of articulation between the proposed highway and the built environment it immediately impacts. Since this is not likely due to the absence of knowledge or stakeholder interest from the community, it could be due – in part – to disciplinary constraints, where traffic engineers and economists portray places of residence and business as origins and destinations and as monetary data points, and not as dynamic environments with potential opportunities and constraints. On a more certain note, the lack of an updated map of villages and towns in central Beqaa certainly discouraged planners and engineers from factoring the built environment in their proposed plans. Lastly, and perhaps more importantly, is the role of corruption in diverting funds away from generating comprehensive plans and equitable outreach to community members and into the accounts of beneficiaries of the clientelist political system. In an interview, Antoine Salamé of Gicome engineers, attributed the poor execution of the Dahr el Baidar and Jdita segments (both in the Beqaa valley) to both corruption and lack of study on the soil profiles of the slopes. Antoine also mentioned that the prolonged timeline of construction required the construction designs to be

revisited and bids to be re-opened, which compromised the quality of the new construction. Recovery from war also played a role in delays and undocumented changes in the built environment, most notably the 2006 Israeli airstrike on the mdeirej segment of the highway, critical in joining the Beqaa to Beirut, leading to loss of finances that would have been otherwise allocated to furthering the construction process. Of the plans produced for the Pan-Arab Highway / Autostrad, the most helpful map was produced by Gicome, highlighting the existing Beirut-Damascus road, the proposed lineal footprint of the highway, the ramps and roundabouts connecting the proposed infrastructure to existing, all in bold colors. The basemap shows topographic lines, river footprints, agricultural plots, and figuregrounds of the existing built environment. These representations begin to shed light on the different typologies of built environment. For example Bar Elias (which was also represented in Doxiadis' maps) appears here one whole dense block with irregular roads whereas Anjar appears as a grid with evenly spaced houses.



Proposed Road alignment for the Pan-Arab Autostrad  
Courtesy of Gicome

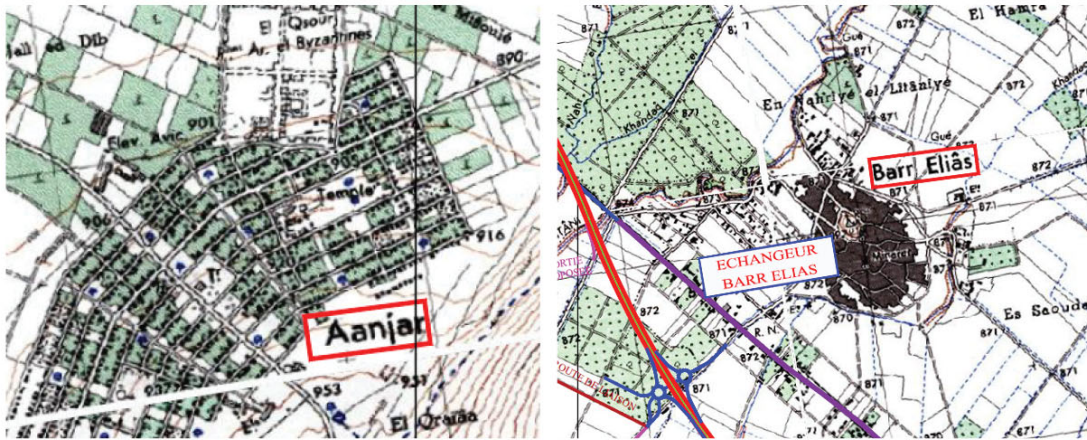


Figure 1.10 Pan-Arab Highway alignment plan developed by Gicome Engineers, 1995.

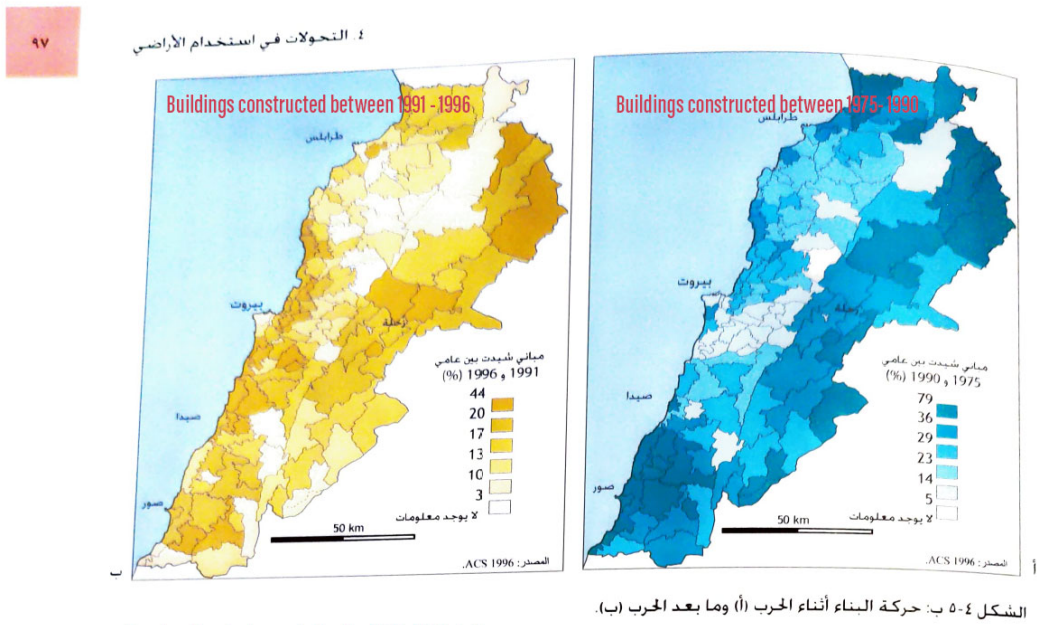
**1990 – present: Remote Sensing** The end of the civil war in Lebanon was quickly followed by governmental and international efforts reconstruct and leverage Lebanon’s economic ability, especially in the banking and tourism sector. The Center for

National Remote Sensing (CNRS) in Lebanon was established in 1995 and conducted many joint efforts with French sponsors to map the country and assess its environmental and urban condition. The most recent tomes by CNRS and partners (2012, 2016) covered the usual spread of topics: historic, economic, political, population by religious majority, infrastructure, watersheds. New scopes included international relations (Lebanese diaspora around the world, international financial partnerships, debt and foreign aid) and planning policy, land use change, refugee settlements, and lastly housing. This set of scopes comprehensively represented Lebanon as an entity and interestingly considered territories beyond Lebanon, almost portraying Lebanon in a post-geographic light. Most of the analysis and infographics were represented on a national scale, but a few zoomed in case studies were included to illustrate some of the major transformations or phenomena in Lebanon such as the impact of inequity in distributions of government funds, water pollution, natural resource and urban growth. In the 2012 and 2016 atlases, the overarching theme was the failure of the state and the mismanagement of resources, which endangers Lebanon's well being on all fronts. The Beqaa was portrayed with significantly greater detail, with ample information that can facilitate understanding how the built, natural, and agricultural environment changed in the last four decades. The Beqaa to date holds the largest percentage of large agricultural lands (over 50%) yielding the largest percentage harvest of fruit, vigniculture, and crops. Olive trees are concentrated on Mount Lebanon and citrus trees are concentrated on the coast. Animal husbandry was also most prevalent in the Beqaa. The total contribution of the agriculture sector was low (6% of the national GPD in 2002), and the surface of individual lands was largely at or smaller than 1.5 hectares (5 acres). Families who harvest their agricultural

lands normally strive to have another non-agricultural source of income (Verdeil et al., 2012b) and employ seasonal workers, a great majority of which are Syrian and who are not paid a living wage (Sajadian, 2020). Normally, denizens of the Beqaa would relocate to Beirut in pursuit of job opportunities or a different standard of living. Precarious security conditions in Beirut during the war halted that relocation, which led to urban growth in the Beqaa, and the construction of multi-storied apartment buildings (2 to 6 floors in addition to the ground floor, which is typically occupied by shops or offices). Maps demonstrated locations that witnessed urban growth, where the Beqaa shows most of its growth in the decades between 1970-1980. Text accompanying the maps and photos on the built environment equated the emergence of residential and mixed-use buildings with the erosion of agricultural landscapes, and even described some of villages (in the Beqaa, Baalbeck, and elsewhere) as being “abandoned by the state”. Apartment buildings constructed in rural areas were quickly dubbed sprawl or conurbations, and land use change was decidedly described as “loss of land cover and natural resources” (Verdeil et al., 2012a). Furthermore, detailed studies described Syrian refugee settlements, their environmental impact, living conditions, and project funded by international aid to support their refuge in Lebanon. To rephrase, the Beqaa to date remains portrayed as disconnected layers with a primarily rural and agricultural character, and the recent atlas positions the Beqaa as an endangered area. In the Beqaa local governance, departments urban planning experienced a lag in technology, which meant GIS data was unavailable and any maps (topography, land use, parcel) were either difficult to access or outdated. However, these data were the closest thing to a base map that informs regional and local planning efforts in the Beqaa. Other nonprofit and

academic entities produced some studies on the Beqaa, but the scope of these studies typically gravitated in the realm of water and agriculture. If the urban environment was at all considered, it was not sufficiently detailed to shed light on its inner workings. The 2005 land use map produced by the CNRS interestingly distinguished 13 categories of land use in the Beqaa. Site-specific categories included sports facilities, archaeological sites, and informal fabric (typically settlements seasonally occupied by nomadic workforce or refugee settlements), and the rest is either urban fabric or urban sprawl. The urban sprawl's subcategories are designated by location. For example, if said sprawl is adjacent to a forested area, it is categorized as "urban sprawl on forest cover", and if it is near agricultural land, it is categorized as "urban sprawl on open field". This nomenclature potentially derived from technical processes in documenting changes in land use. When a land changes from forested to built, the technician responsible of reclassifying the map likely added the environmental context to the urban fabric category. Alternatively, the nomenclature of the urban fabric could have been generated by considering the land cover of the adjacent fields. Intentional or not, this reinforces the theory that the character of the environmental and agricultural character of the Beqaa persists even in the classification of the built environments. It remains, to date considered

more of a land of resources than a human habitat. However, to the regional or town



Construction during and after the 1975 - 1990 civil war.



Portrayal of urban growth in Lebanon in Atlas du Liban  
Source: Verdeil, Faour et al. 2012

Figure 1.11: Excerpts from the Atlas of Lebanon, 2012

planner, this does provide context to the built environment and could be treated as a more detailed description of these urban sprawl categories

Most of the maps produced in the 2012 atlas attributed statistics to the boundaries of cazas and municipalities when acceptable. They were represented in graduated colors or charts attached. Of greater significance was what data was included and how did it help craft the arguments and portrayals of Lebanon.

**1940's - 60's Military Cartography:** Military cartography was created for many areas of Lebanon by U.S., Syrian, and Soviet governmental geographic divisions. Access to much of these cartographies remain restricted. In the declassified maps, the layers scope covers topography and tree cover and seldom considers the built environment. The Lebanese Army Directorate for Geographic Affairs was established in 1962, and continued generating cartographic of the same landscapes in the 60's and 70's. Later efforts migrated to Geospatial Information Systems (GIS). These data were not considered for this paper, but that is not a reflection of their lack of importance.

### **3.2 Trends in findings**

In the cartographic elements that were used to study the region of the Beqaa valley, there are a few distinct trends that emerge throughout history.

- 1) Historically, the Beqaa was – and continues to be – considered primarily a land of natural and economic resources. Studies on watersheds, agricultural and natural tree cover are typically used to inform regional planning policies and to leverage the Beqaa. Its built environment is secondary to its agricultural and touristic functions, which

overlooks the intricacies and potential of its communities to operate within what is described as a failed state.

2) Trade routes were the organizing element in shaping the urban fabric in the Beqaa Region. Transportation planning, both in railway the Pan-Arab Highway was concerned with facilitating freight transport from the Beirut port into Damascus, and in turn to other inland dry ports. By connecting major strategic nodes, both military and economic, the Beqaa began gaining strategic value. These nodes were personified in Riyyak’s military airport, and Zahle’s industrial city. While studies on cities and towns are not completely absent, they are typically conducted on very distinct locations to promote historic preservation and touristic opportunities. In that, the Beqaa’s urban form was never documented or planned with the same attention afforded to cities such as Beirut or Tripoli.

<b>Table 2: Summary of Cartosemiotic analysis</b>					
<b>Map</b>	<b>Year</b>	<b>Intent / Context</b>	<b>Scope</b>	<b>Component length</b>	<b>Legend/Symbol</b>
World Maps	500-1500	document the world, application of mathematical and geographic theory	World	<ul style="list-style-type: none"> <li>■5 components to represent land cover, topography, and water.</li> <li>■1-2 components to represent cities and regions.</li> </ul>	<ul style="list-style-type: none"> <li>■A legend key is not clearly displayed. Illustration techniques add nuance to represent the character of the terrain.</li> <li>■North Arrow is visible.</li> <li>■Title of the work and name of the author is sometimes present depending on who is adapting the map.</li> </ul>

<b>Map</b>	<b>Year</b>	<b>Intent / Context</b>	<b>Scope</b>	<b>Component length</b>	<b>Legend/Symbol</b>
Suriah va Beirut Vilayetler	1909	Political claims, documenting territorial governance.	Ottoman Empire	<ul style="list-style-type: none"> <li>■5 components to represent land cover, topography, and water.</li> <li>■3-4 text components to represent cities and regions.</li> <li>■2 components to represent boundaries.</li> </ul>	<ul style="list-style-type: none"> <li>■A legend key is not clearly displayed. Illustration techniques add nuance to represent the character of the terrain.</li> <li>■North Arrow is absent.</li> <li>■Scale is visible.</li> <li>■Title of the work is visible.</li> </ul>
Atlas Economique du Liban et la Syrie	1926	Re-inforcing the need for the French mandate.	Lebanon and Syria	<ul style="list-style-type: none"> <li>■4-9 thematic components depending on the map's topic.</li> <li>■3-5 text components to represent cities and regions.</li> <li>■2-4 components to represent boundaries and transportation networks</li> </ul>	<ul style="list-style-type: none"> <li>■Legend keys are clearly displayed, but do not list all the symbols used in the map.</li> <li>■Maps are intricately illustrated, but there is less reliance on nuance.</li> <li>■North Arrow is absent.</li> <li>■Title of the work and the author name is present.</li> <li>■Scale is visible.</li> </ul>
The Plan for Lebanon	1958	Mapping cities and towns of Lebanon to recommend housing policy.	Lebanon	<ul style="list-style-type: none"> <li>■2-9 thematic components depending on the map's topic.</li> </ul>	<ul style="list-style-type: none"> <li>■Legend keys are clearly displayed, and there is little additional information not listed in the key. Maps are minimalistic.</li> <li>■North arrow is present.</li> <li>■Title of each map is present.</li> <li>■Scale is visible.</li> </ul>

Map	Year	Intent / Context	Scope	Component length	Legend/Symbol
Proposed Road alignment for the Pan-Arab Autostrad	1970 - 1995	Mapped and construction documents for the proposed	Beirut-Damascus corridor	<ul style="list-style-type: none"> <li>■6 components to designate proposed and existing road networks, rail, towns and access points.</li> </ul>	<ul style="list-style-type: none"> <li>■Legend keys are not displayed, but a clear symbology is used to designate the components.</li> <li>■North arrow is not present.</li> <li>■Title of the map and the author is present.</li> <li>■Scale is present.</li> </ul>
Lebanon Atlas	2012	Documenting the condition of the natural, agricultural, and built environments and socio economics of the Lebanon.	Lebanon	<ul style="list-style-type: none"> <li>■2-10 components depending on the theme of the map. Graduated or discrete symbols.</li> </ul>	<ul style="list-style-type: none"> <li>■Legend keys are clearly displayed, there is little additional contextual information. Maps are simple.</li> <li>■North arrow is not present</li> <li>■Title of the map and data sources are listed.</li> <li>■Scale is listed</li> </ul>

#### 4. Conclusion and discussion: Critical Cartography in Context

Due to technological development and the widespread availability of mapping software and data, governmental elites are no longer the sole authority on map making. Indeed, with the decrease of technical and monetary cost of mapmaking on one end, and the increase of data, the ability to make a map, is now available to anyone with access to the Internet. This has empowered the public to generate alternate representations of space for civic and commercial needs, which in turn raises the need for critical cartography.

Following independence, Lebanon's history was rife with impactful events. These include the arrival of Palestinian refugees in 1948 to Lebanon and the corresponding establishment of Palestinian refugee settlements in Beirut and its peripheries, and the

arrival of Syrian refugees in 2011 and the establishment of refugee settlements around Lebanon, but mostly in the north and in the Beqaa. Violence was a recurring theme, most notably in the 1958 and the 1975-1990 civil wars, and the 2005 assassinations of political figures starting with Rafiq El Hariri. Lebanon and Israel's tense relationship broke into violence more than once, with the Israeli invasion in 1982, and mass scale Israeli attacks that caused human life and territorial casualties in 1996 and 2006. While Lebanon regained the Shebaa farms which were occupied by Israel in the year 2000, the southern border separating Lebanon and Israel remains prone to scattered violence.

Lebanon's internal organization also shifted with internal fissures, some along political parties operationalization of land development and management to assert power and control via governmental and private sectors (Bou Akar, 2018). The fragmentation of Lebanon's space was also a response to the failures of the state (Arsan, 2018).

Cartographies produced in post-mandate Lebanon increased in accuracy and quantity especially with the continued development of remote sensing and military mapping technologies. Lebanon's directorate of Geographic affairs was established in 1962 and the Center for National Remote Sensing (CNRS) was established in 1995, which shifted the all-purpose mapping authority to the Lebanese state. With Lebanon's last 80 years there has yet to be an emerging narrative, cartographic or otherwise, on what the Lebanese community is beyond a victim of corrupt governance and violence.

There is a definite need to rethink how Lebanon cartographically represents the Beqaa as part of the country, specifically to represent the region on more realistic grounds. The urban fabric in the Beqaa is intricate and multifaceted beyond the agricultural and the natural realms. The reach of Lebanon's national planning efforts may

be limited in the Beqaa, whereas local governance such as municipalities and the litany river authority, educational institutions, and others can use more detailed spatial information to gauge methods of sustainable development. In that sense, an updated mapping methodology, rapid and comprehensive, is necessary.

With the current technological advancements in open mapping, community-based knowledge, and citizen science, integrating input from the denizens and local institutions of the multiple areas can go beyond the existing binaries (planned and unplanned, central and sprawl) towards categories, or even a spectrum, that reflect how the built environment functions, to what needs it responds to, and how well it serves its denizens. Non-profit and academic entities are leading the way for more pluralistic approaches to mapping such as Public Works Studio (Public Works Studio Projects, 2020) documenting issues like as environmental dangers of stone quarries owned by the political ruling class (2020) (باستديو أشغال عامة, 2020) and the right to equitable housing by harvesting narratives from the residents of the studies towns, villages, and neighborhoods and activating public input via launching of competitions or public forums (2020) (باستديو أشغال عامة, 2020) that are less concerned with standardization of a corpus of spatial information according to fit the traditional part of an atlas. Another example that ties financial structures. Other examples that leverage the art and science of cartography today include critical mapping at the Beirut Urban Lab, a research lab at the American University of Beirut investigating issues that speak to the very ontological question of how Lebanon is mapped. A very relevant example of that is rethinking the boundaries of Beirut neighborhoods and considering the new role of map production in an age of data availability (Gharbieh,

2015) and also migrating some of the atlas components from static layers towards living atlases and online databases (Beirut Urban Lab, 2020).

Another example is Visualizing Palestine, a group of researchers, designers, and technologists utilizing data to advance a factual, rights-based narrative of the Palestinian-Israeli issue. Their platform, Palestine Open Maps (Palestine, 2018), shows the historic changes in Palestine, shedding light on the displacement, violence, and reconstruction of the built environment. For all three examples mentioned, it is important to note that visual design is a critical element to their success, which is to say abundance of availability in data does not necessarily mean that atlases or maps are obsolete. Quite the contrary: cartography is, if anything, more needed to manage spatial quantitative and qualitative data to produce visuals that are legible and functional.

In the case of the Beqaa, borrowing from counter-mapping practices would engage the layered geographies inherited from the Ottoman and colonial lenses to reverse the notions of the Beqaa being an agricultural/touristic resource first, and a habitat second. Counter mapping in this case is not necessarily the critique of fallacies of the existing system, but it is an alternative examination of the decisions taken to produce cartography and the communities they represent. (Crampton & Krygier, 2006). Producing maps that reflect the intricacies of the land uses and growth patterns of the built environment can borrow from the same map-making techniques currently deployed by the National Remote Sensing Center in Lebanon. Added data points and networks of localities significant to the Beqaa communities can then institutionalize community-based or counter-mapped geographies for future regional and local regional urban and environmental planning initiatives.

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**ARTICLE 02: GENERATING A LAND USE CLASSIFICATION SYSTEM  
FROM URBAN MORPHOLOGY: THE BEQAA VALLEY, LEBANON <sup>2</sup>.**

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<sup>2</sup> *Lynn Abdouni, Landscape and Urban Planning Journal, to be submitted..*

## **Abstract**

This paper assesses the Land Cover Land Use (LCLU) system currently used by the National Remote Sensing Center (NRSC) in Lebanon to classify the built environment in the Beqaa valley, and proposes an alternative classification based on a comprehensive morphological analysis on the characteristics of the built environment. The Beqaa Valley in Lebanon are a stretch of agricultural landscapes interlaced with forested and arid regions, home to two medium-sized cities (Zahle and Baalbeck) and several small towns and villages. The proposed workflow deploys research techniques in urban morphology using the following criteria: street grid, density, open space, architectural character, and land use mix to propose typologies for the built environment. The resulting typologies inform a revised LCLU system that would facilitate the production maps that can inform regional and local planning for the built environment in the Beqaa valley.

## **Article Map**

The introduction in this article begins by situating the ‘informal’ and ‘vernacular’ built environments as equal and legitimate aspects of the town or city, and by positioning the town or city as an organism weaved from these built environments (2.1), rather than a dichotomy of formal and informal. It then proceeds to describe land use classification systems typically used to create regional maps and city maps, and potential contributions that urban morphology research can provide to create a land use classification system that reflects the built environment and its informal and vernacular aspects. (2.2). This is followed by a brief historic and geographic description of the Beqaa valley in Lebanon with emphasis on aspects of vernacularity and informality prevalent in the built environment(2.3). The goals of the introduction are: 1) highlight how land use

classification systems overlook the intricacies of the built environment especially in areas with a predominant vernacular and/or informal characteristics; 2) justify the extrapolation of methodologies and techniques specific to investigating the informal and vernacular environments to encompass mapping the entire built environment.

The methods section proposes a methodological workflow that is conducted in five phases: *Reconnaissance, Initial Analysis, Data Collection, Analysis, and Interpretation/Operationalization*. This workflow connects urban morphological research to remote sensing research by deploying typo-morphology, an urban morphology technique to classify built environments and generate a land use classification system that can guide mapping the built environment of the Beqaa Valley.

The results section describes findings by phase and proposes an alternative land use classification system that can be used in mapping the Beqaa valley.

## **1. Introduction: Mapping the Informal and the Vernacular**

### **1.1 Informal, Vernacular, Formal: Conceptual and Spatial Boundaries.**

#### **Informality**

The informal urban fabric is typically considered as a built environment designed and constructed without authorization from the state (Roy & AlSayyad, 2004) and is also thought of as “a spontaneous, uncontrolled response to the mass urbanization rapidly sweeping the globe” (Lejano & Del Bianco, 2018). Exemplified in slums, favelas, comunas, kampungs, bidonvilles, barriadas, refugee camps and migrant settlements, the

informal environment is a mechanism for the poor and disenfranchised population to find lodging in cities that would otherwise be unaffordable. Informality is typically considered restricted to informal settlements in the city thus considered as extraneous to the ‘formal’ city. This dichotomy is evident in the land-use maps generated for urban planning, where informal settlements are typically mapped as a separate fabric with sharp boundaries that distinguish it from the city fabric. This cartographic representation of the built environment reinforces the conception that informality is restricted to these demarcated settlements. However, there is ample evidence to suggest the contrary: informality is not necessarily restricted to what is classified as “informal settlements” and their contributions are not extraneous to the city. On the contrary, informality is integral and even essential to the function of the city. Dharavi, an established slum in the outskirts of Mumbai, hosts enterprises and factories allowed to operate by the state due to their economic return. not only benefiting Dharavi, but the entirety of the city of Mumbai, despite the facilities’ non-adherence to governmental codes and regulations (Sharma, 2000). In Lebanon, refugees, nomadic workers, and migrant workers are housed in government designated refugee camps and informal settlements, but also in buildings enmeshed within the ‘formal’ city fabric such as janitor suites in residential mixed-use buildings and in unfinished structures (UN Habitat & UNHCR, 2018). The refugee/nomadic/migrant workforce in Lebanon, regardless of their housing locations, provide the necessary labor to sustain the Lebanese agricultural, construction, and service sectors (Krijnen & Fawaz, 2010; Reumert, 2021; Sajadian, 2020).

Roy and Alsayyad’s ‘Urban informality : transnational perspectives from the Middle East, Latin America, and South Asia’ posit that informality in governance,

economy, and processes of building the environment are not strictly an issue of the poor, but also well within the scope of the middle class and even in the elite (Roy & AlSaiyyad, 2004). The relationship between entrepreneurship and informality is a growing area of research, where the entrepreneur does not necessarily choose informal work out of necessity, but may choose it for its profitability (Gurtoo & Williams, 2009; Maloney, 2004). This then broadens the context of informality and informal work outside the built confines of informal settlement and the ‘third world country’ and positions ‘informality’ a legitimate pillar of the national economy, regardless of social or economic class and regardless of location (Banks et al., 2020; Jaffe & Koster, 2019; Williams, 2007). Governmental investment in growing the informal employment sector presents a viable path towards recovery from economic hardship, especially in countries that struggle with perpetual crises or governmental inefficiencies (Debrah, 2007). Despite the persistence of gender-based inequities – such as limitations enforced by gender roles and difficulty in accessing financing options – in the informal employment sector, the flexibility it provides can facilitate work opportunities for women more readily than the ‘formal’ sector (Fapohunda, 2012; Olu-Owolabi et al., 2020). In essence, informality in its spatial, economic, and societal form is inextricable from the region, the city, or the town where it dwells and must be considered as an integral facet of the town, city, country, or region where it is manifested.

### **Common Grounds: Informality and Vernacularity**

In step with breaking informal labor out of its conceptual confines, informal and vernacular built environments can also be positioned as integral aspects of the town, city, or country. In viewing the vernacular, informal, and formal built environments, the

boundaries sequestering the ‘formal’ from the ‘vernacular’ are not as stark as those separating the ‘formal’ and the ‘informal’.

The ‘vernacular’ architecture is the built habitat that is constructed without the intervention of a trained architect or a specialist designer (Glassie, 1990; P Oliver, 2007), that retains some of the urban and architectural historic heritage while aspiring to modernity and negotiating with the technological and resource opportunities and limitations imposed by the environment (Bourdier & AlSayyad, 1989). There is a considerable overlap – conceptual and methodological – between ‘traditional’ and ‘vernacular’ built environments, where the ‘vernacular’ built environment is considered a subset of, interchangeable with, or separate altogether from, the ‘traditional’ environment (N AlSayyad, 2014). While distinctions between the two can shed light on the historic and socio-cultural context that produced these built environments (Carlos et al., 2015; Kamalipour & Zaroudi, 2014), and how traditional versus vernacular architectures reflect changes in the identity of their dwellers’ communities (Jani, 2011). this paper does not aim to contribute to this distinction, but is rather aligned with the effort to expand the disciplinary and spatial boundaries of vernacular research (A. Green, 2007; Maudlin, 2010). The aim is to utilize any and all documentation methods deployed for built forms considered antithetical to the ‘formal’, the ‘planned’, and the ‘designed’ built environment. The term ‘vernacular’ here then encompasses ‘traditional’, ‘indigenous’, ‘folk’ and ‘vernacular’ architecture.

The agency of the dweller in the production of the built environment creates the basis for common grounds between the ‘vernacular’ and the ‘informal’ architecture. In both cases, vernacular and informal, the dweller is also often the builder who adopts

community-based or traditional construction techniques to create a habitat that suits their needs, negotiates with material/economic/environmental limitations and constraints, and aspires to modernity – be it architectural or technological (Hubka, 1979; Turner & Fichter, 1972). The intermingling of vernacular and informal can be observed in the shape and distribution of public spaces and building façades (Kamalipour & Dovey, 2019), emerging transportation networks and the built environment’s response to those networks (Samaha & Mohtar, 2020), change in the fabric of the built and agricultural environment (Chai & Seto, 2019), and the juxtaposition of land uses and architectural characteristics (Kamalipour & Dovey, 2019; Khan et al., 2021).

## **1.2 Remote Sensing and the Vernacular Built Environment.**

### **LCLU Classification Systems for Urban Research.**

Remote sensing (RS) is the process of acquiring and analyzing information about a geography or phenomenon from a distance (Jensen, 1986b; Lillesand & Kiefer, 1987c). Earliest forms of remote sensing data can be traced back to the early 1900’s where photos of cities were from hot air balloons and homing pigeons. Remote sensing imagery captured by satellites emerged in the 1950s. They were used for a broad range of military goals, and later earth sciences and research ramifications such as forestry, ecology, water and air quality, and urban research. Image classification, defined as the process of categorizing imagery, captured by any visual recording device, into pixels or objects, is an essential step in preparing Land Cover Land Use (LCLU) maps from satellite imagery.

Land Cover data conveys the distribution of forests, wetlands, built environments, agriculture, and water landscapes in any particular region whereas Land Use data describe how people use these lands (National Oceanic and Atmospheric Administration, 2022). Today, the terms Land Cover and Land Use are used interchangeably, and often in conjunction. The source of this annexation between the two is the development of medium resolution imagery in the 1970's and the governmental desire for actionable spatial information that enables them to manage and plan for resources and urban development (J. R. Anderson, 1976). With the further development remote sensing analysis data and capabilities, there is a desire to separate Land Cover data from Land Use data (Comber et al., 2008), but in most cases, especially in the cases of datasets that characterize regional landscapes that include natural, agricultural, and built landscapes, Cover and Use are typically portrayed in one system.

The process that translates raw spatial data such as spectral (measured by wavelengths, radiation) or Lidar (Light Detection and Ranging) into information classes is called classification. Classification entails identifying an area of relative uniformity and homogeneity and assigning it to a category suitable to the intended map usage (Lillesand & Kiefer, 1987a). Identifying characteristics of homogeneity while balancing the scale, detail, and legibility of the area and class in question renders setting classification systems surprisingly challenging (Campbell, 1983). Broad, coarse, and general LCLU classification systems include the International Geosphere-Biosphere Program IGBP Land Cover Classification System (Loveland et al., 1999), the U.S. Department of the Interior Fish & Wildlife Service Classification of Wetlands and Deepwater Habitats (Wetlands Subcommittee, 2013), the U.S. Geological Survey

LCLU Classification System (J. R. Anderson, 1976) and the U.S. National Vegetation and Classification System. These systems are concerned with characterizing the land cover (vegetation, soil, water, paved) to generate the spatial knowledge necessary for preliminary research. LCLU classification systems for urban planning can also be generated such as the American Planning Association Land-Based Classification System (American Planning Association, 2001), and COoRdination of INformation on the Environment (CORINE) deployed in 1985 to systemize land use and land cover mapping in the European Continent.

Recent critiques of the most popular classification schemas for urban studies claim that the often-coarsely classified built environment and over-generalized categories neglect the specificities and functions of cities and towns. The need for finer-scale empirical surveys and to generate land use classification system that pay more attention to the heterogeneity of the urban fabric, and challenge the preconceived and often misleading perceptions on the nature of cities and towns . To remedy this gap, mapping approaches for the urban and built environment took different directions. To mention a few, developing a more expansive classification set such as HERCULES (Cadenasso et al., 2007), creating composite classes that represent heterogeneous nature of the built environment (Hamstead et al., 2016), or using proxies and/or research-specific criteria that complement or enhance exiting land use classification such as utility allocation (Geiß et al., 2011) water management (Bach et al., 2015), night-time satellite imagery (Fan et al., 2014).

Using physical characteristics of the built environment fabric to generate classification schemas that are specific both to the research intent and the area in

question. Using physical aspects to infer land use mixes generates classification sets that can facilitate a multitude of urban planning interventions. Ye and Van Nes used functional mixes to generate classes for future measurement of socioeconomic performance, thus determining which functional mix is optimal in future planning efforts (Ye & Van Nes, 2014). A classification of street networks and buffers generated from the Multiple Fabric Assessment (MFA), a method devised to position urban fabrics from the pedestrian perspective by Araldi and Fusco (Araldi & Fusco, 2017) yields a classification system applicable to immediate buffers of street networks, by area and distribution of the public space, building height and character, frequency of node occurrence, thus prioritizing the pedestrian experience in the generation of classification sets (Araldi et al., 2018). Figure ground Maps, conceived in 1748 by Gianbattista Nolli and revived by Colin Rowe in the mid-20<sup>th</sup> century, can easily be used as a visualization technique transferable to represent and classify the landscape (Bustamante, 2020), and to compare city textures (Boeing, 2021). Thus tapping into characteristics of the built environment can produce informative and compelling maps. With the continued technological advances, marrying remote sensing analysis techniques and urban morphology techniques is feasible. This is reversing the primary role of classification criteria from a being vehicle for standardization to a method that captures the specificities of the area of study.

### **Urban Morphology for Vernacular and Informal Environments**

Urban morphology is defined as the study of the built fabric, and the processes and people shaping it (International Seminar of Urban Form, 1990). This interdisciplinary sub-discipline was anchored in three schools: The Conzenian school,

led by M.R.G. Conzen addressing built environments in UK and the US, the Muratorian school, led by Saviero Muratori in Italy, and the French school of thought, spearheaded by Philippe Panerai and Jean Caste (Vernez-Moudon, 1997). The motivations of urban morphological study can be housed under two foci: focus on the object of study, which is to understanding the complexities of the built form; and focus on the manner and purpose of study, which is the analysis of the evolution of the built city, or morphogenesis and the distilling of normative modalities that guide future planning goals (Marshall & Çalışkan, 2011).

The branching out of the three schools outside the US and Europe and into the built landscapes of South Asia, the Middle East, and Latin America, including the informal and vernacular landscapes of these regions, called for research to address the epistemological question of the built environment. Scheer posits urban morphology, a field distinguished upon the premise that knowledge is gained through the comparison of physical forms from places, and its reliance on field visits to capture the specificities of the built environment, as a research method. She proceeds to state that urban morphology's "data and methodology are at least as reliable as other social science contributions to planning." (Scheer, 2019), a statement echoed in recent work (Beauregard et al., 2018; Ponzini, 2018). Ongoing developments in mapping urban morphology can be productive in understanding the informal, vernacular and unplanned environments where zoning is non-existent. Reciprocally, techniques developed to understand the rich and intertwined composition of the informal, vernacular and unplanned environment can be extremely useful in mapping the 'formal' urban environment (Jaffe & Koster, 2019) and in some cases can pose questions on whether

formal methods of planning the built environment are successful (Scheer, 2013). On the study of traditional and vernacular architecture, Dell Upton defined studies under five avenues: the object-oriented studies, concerned with the built environment and how they were constructed; socially oriented studies, where the built environment is examined as evidence for the past; culturally oriented studies, which explores the cultural implications and constructions of the built environment; symbolically oriented studies, which delve into the symbolic dimension of architecture; and design-oriented studies that are concerned with affirming regional identity (Upton, 1983). With commonalities of the theoretical and motivations between vernacular architecture research and urban morphological research, using morphological approaches to study vernacular is intuitive if not warranted.

Adding to connection between remote sensing and other disciplines that are concerned with geospatial analysis stated above, the urban morphology to the production of maps is a developing research avenue: in their work 'Mapping Urbanities', Dovey, Pafka and Ristic delve into physical aspects of the built environment such as formality and informality as well as more theoretical concepts such as meaning mixes of functions (Kim Dovey & Pafka, 2018). Their quest to understand the connection between the spatiality and the sociality of the of the city is heavily guided by assemblage theory, which promotes the practice of looking at relationships, synergies, and symbioses characterize and communicate the representation of the city (Deleuze & Guattari, 2004).

### 1.3 Overview of the Built Environment in The Beqaa Valley

Lebanon is located on the eastern shores of the Mediterranean Sea and shares borders with Syria and Israel. Two mountainous ranges run from NorthEast to SouthWest Lebanon, separated by the Beqaa Valley, a stretch of agricultural and natural landscapes anchored by two cities (Baalbeck and Zahle) and a constellation of towns and villages. Lebanon is often portrayed as a country fragmented by frequent changes in governance throughout history, yet solidly anchored as a strategic location in the Middle East due to its port cities and international ties, which began flourishing during the Phoenician age (Harris, 2012). Lebanon was under Roman, Seleucid, Arab, Ottoman, and French rule, and while the impact of these eras was manifested differently between shore cities, mountain towns, and Beqaa towns, historic traces both clear and implicit are evident in today's built environment. In the Beqaa, the most striking evidence include historic ruins such as the Umayyad castle of Anjar and the Roman temple of Jupiter in Baalbeck. More subtly, in the architectures and urban vernacular of the everyday, persist traces of Islamic city planning, Ottoman rule, and French colonialism, which can facilitate the legibility of the vernacular-built environment. It is important to note that the population of the Beqaa was, until recently, low. Doxiadis, an urban planner who visited Lebanon in the 1950's assessed the Beqaa population at roughly 193,000, Beirut at 350,000 and Mount Lebanon at 400,000 (Sarkis, 2003). Beqaa population was estimated at 490,000 in 2007 (إدارة 2008 الإحصاء المركزي). The Lebanese population in the Beqaa likely increased since 2007, without counting the 300,000 registered Syrian refugees (UNHCR, 2021) in the Beqaa today . The bulk of the environment built to accommodate the increase in the population is 70 years old or less.

Today's Beqaa is composed two administrative Cazas, The Beqaa and Baalbeck-Hermel. Aside from its two main cities, Zahle and Baalbeck, its remaining towns are smaller in size, with historic parts evidently established prior to the commercialization of the car, characterized by small houses dressed with stone and red brick roofs, and separated by narrow winding roads. More recent quarters of towns are demarcated taller buildings aligned along wider roads. Towards the end of the Ottoman Empire, the Beirut-Damascus rail line was established which dictated, to some extent, the growth patterns of towns that hosted stations (Jdita, Mrejat, Saadnayel, Maallaka, Riyyak, and Yahfoufa). The rail's operations slowed with more Beqaa's and Lebanese citizens purchasing cars, and ceased completely during the civil war of 1975-1990. This is evident in the juxtaposition of narrow, organic streets with wider, more uniform street grids. Outside towns, agricultural plots punctuated by one or two buildings are commonly seen in the Beqaa, where land owners opt to dedicate a portion of their land for a family residence (villa) or an extended family residence (apartment building). Industrial lands are found clustered in what locals refer to as 'Al Madina al Sina'iyya' on the fringes of Zahle or in Taanayel. The incremental and historic nature of towns in the Beqaa is evident, except for a few locations: the town of Anjar was visibly planned (Foote, 2000); residential developments or planned communities akin to New Towns (Keeton & Nijhuis, 2019) are emerging on the fringes of smaller towns, such as the Haoush Mandara development and fenced apartment complexes that sport semi-private public spaces for building residents. These developments are also emerging more prominently in other areas of Lebanon (Glasze & Alkhayyal, 2002). Recent refugee waves resulting from the onset of the 2011 Syrian war are typically housed in shelters, aligned in a grid in distinct land parcels.

Outside these refugee camps, Syrian migrant workers in Lebanon's agriculture, construction, and industrial sectors also seek shelter in settlements of semi-permanent structures on town fringes or near agricultural lands (Joseph, 2013; Sajadian, 2020). The Beqaa's economic contribution to Lebanon stems from its agricultural lands and vineyards and the touristic attractions orchestrated around historic sites the temple of Jupiter, Anjar ruins, and the Berdawni river. Outside these frameworks (agricultural, and historic-touristic) the built environment in Lebanon is often overlooked or deemed detrimental to the natural value of the Beqaa.

## **2. Methods**

This section builds upon the established conceptual viability of link between the urban morphology research and land use classification systems to summarize methodologies in urban morphological research that are transferable to remote sensing.

### **2.1 Methods in urban morphology and vernacular research**

In 1957, Doxiadis, an internationally known urban and regional planner and his team arrived in Lebanon to conduct a study that aims to inform the Lebanese Government's housing plans and policy. Due to the pressure placed by the Lebanese government on Doxiadis and the lack of census and cartographic data, the team resorted to visiting 1680 towns and villages, collecting photos and diagrams of the town's centers and commercial streets, and conducting informal conversations with town dwellers and local government officials to contextualize their findings (Sarkis, 2003). The team's findings were compiled in a report with recommendations for housing policies and model

villages but these recommendations were never implemented partially due to the 1958 civil war and partially due to a change in government and national priorities.

Doxiadis' documentation techniques can easily be categorized as methodologies in urban morphological research for vernacular architecture, especially considering the team's interest in ordinary places of the everyday and seemingly unimportant artefacts (the team documented electricity transformers, water canals, construction sites, trash bins) and the migration from secondary data (historic records and cartographies) to primary data (field observations and documentations) (Carter & Collins Cromley, 2005). While these methodologies can be described as common sense and not necessarily bound by discipline, the scholarly discourse on urban morphology and methods in morphological research began unfolding in the 1970's, with the emergence of distinct units of interest for urban morphological research. First, the urban form is defined by three fundamental physical elements: buildings and their related open spaces, plots or lots, and streets. Second, the urban form can be understood at different scales: the building/lot, the street, the city, and the region. Third, urban form can only be understood historically because it undergoes continuous change (Vernez-Moudon, 1997). Urban morphological research often relies on these spatial elements and their scale as organizing denominators, especially in typo-morphological analysis and the typological process, which was attributed to the Italian school of thought to document continuity and change of the built environment through history (Caniggia & Maffei, 2001). The process of identifying objects and scales for comparison and the characteristics of distinction can provide grounds upon which a cognitive inquiry or perhaps a grounded theory (Oliveira, 2016) would be constructed to understand the vernacular and informal built environment

while avoiding the normative impulse to conform the case study to existing notions of what the built environment ought to be. In the same vein, Kropf highlights the necessity of allowing room for an iterative process, moving between several phases of primary and secondary data collection and analysis to build a comprehensive framework (Kropf, 2017a) as illustrated in figure 2.1.

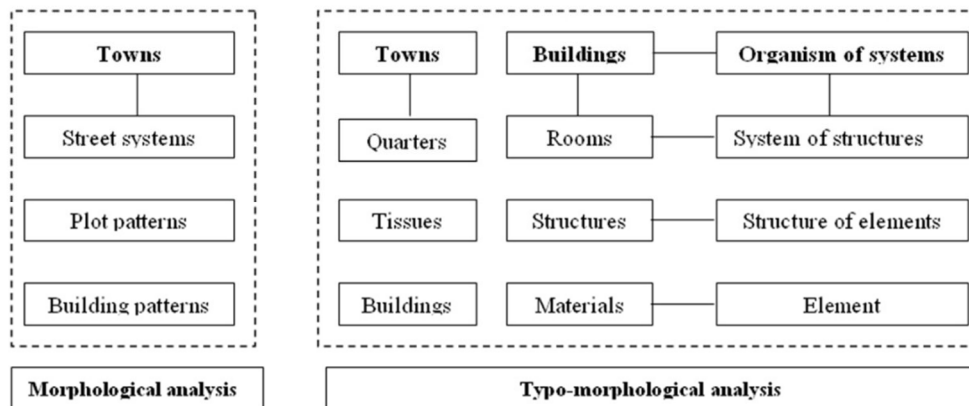


Figure 20.1. Analysis framework for morphological analysis. Sima and Zhang, 2009.

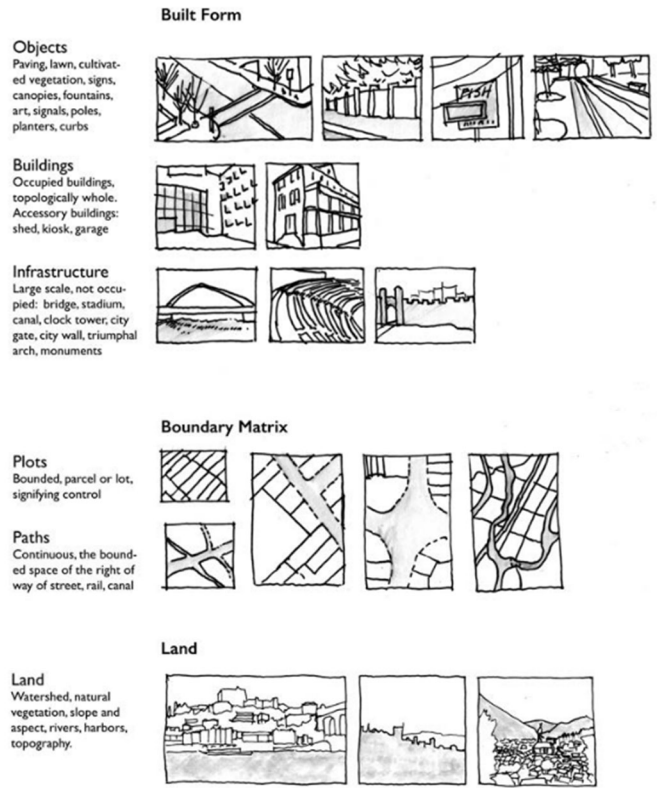


FIGURE 10.2 Categories of morphological data (drawn by Brenda Scheer).

Figure 2.2: Categorization in morphological analysis. Scheer 2016.

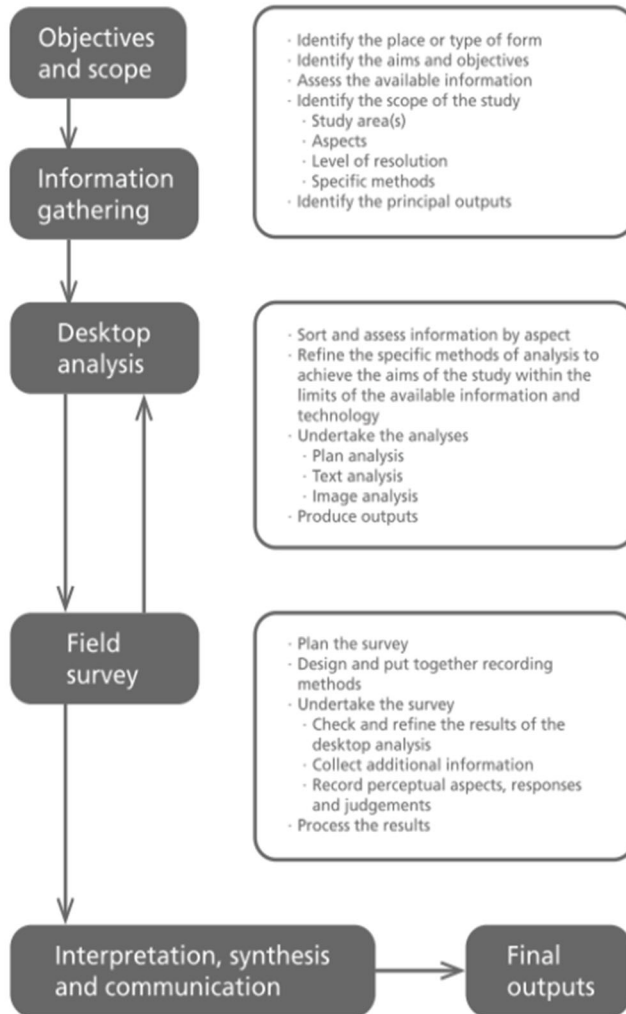


Figure 5.1  
Diagram showing a general sequence of steps that make up a morphological study.

Figure 2.3. Typical morphological study sequence. Kropf, 2017

## 2.2 Proposed methodological workflow

Following the iterative approach adopted in urban morphological studies (Carter & Collins Cromley, 2005; Fan et al., 2014; Kropf, 2017b; Scheer, 2016; Whitehand et al., 2014), the methodological workflow was sequestered into 5 phases starting from reconnaissance visits and acquisition of secondary data, of which the most significant

was the LCLU classification set produced by the Remote Sensing Center in Lebanon to a systematic collection of the data, to a systematic collection of primary photographic and geospatial data, to an typo – morphological analysis to address the gaps and inconsistencies in the LCLU map adopted by the remote sensing center of Lebanon (see figure 2.4 for a summary).

**Phases 01:** Initial collection included harvesting spatial and archival data (GIS layers, cartography, building census etc.) and field observations. This established the spatial knowledge ‘baseline’ upon which regional and local research and planning endeavors are conducted. Field observations including diagrams, photographs, informal conversations with residents and shop owners as well as semi-structured interviews when applicable were conducted.

**Phase 02:** This included an examination of the classification system used for LCLU map in the Beqaa valley, with special emphasis on the classes representing the built environment. Comparing diagrams collected on the field with LCLU classes classifying the built environment revealed areas that could be improved for a more comprehensive representation. Notable built environments or aspects of the built environment were extracted from the diagrams, photos, and secondary dataset collected in Phase 01. This preliminary analysis informed the design of a morphological survey on ArcGIS Survey 123.

**Phase 03:** 500 data points were collected from a sample of the built, agricultural, and natural landscapes in Central and West Beqaa Valley. Sampling was conducted either from the center of a town or village moving outwards to the agricultural or natural fringes, or moving inwards from a main road (Beirut-Damascus Main road, Zahle –

Baalbeck) to the center of the town or village. The center of the town or village was typically a plaza adjacent to a religious establishment (mosque/church), or a commercial district/strip. When sampling from main roads to the center of the town, the point of entry was either a landmark (hospital, school, public service) or a node connecting the new Pan-Arab Highway to the old Beirut-Damascus main road. Photographs and notes were collected for 250 of those points for further detail. All the built environment points (170 in total) and the industrial points (35 in total) were entered with photographs and notes. The collected points were uploaded to the ArcGIS Survey 123 online database for download and analysis.

**Phase 04:** Upon comparing the photos from the sample locations, it became clear that the assemblage of materials and styles in the construction of buildings, the street grids, the shape and use of open spaces distinguished built environments between towns and between locations of towns (center to periphery). To compare the different aspects of these built environments, data points were entered into a matrix that addressed street grid, architectural style, land use, density, and open space type.

**Phase 05:** The typo-morphological results from the matrix were then used to propose adjustments to the LCLU classification set.

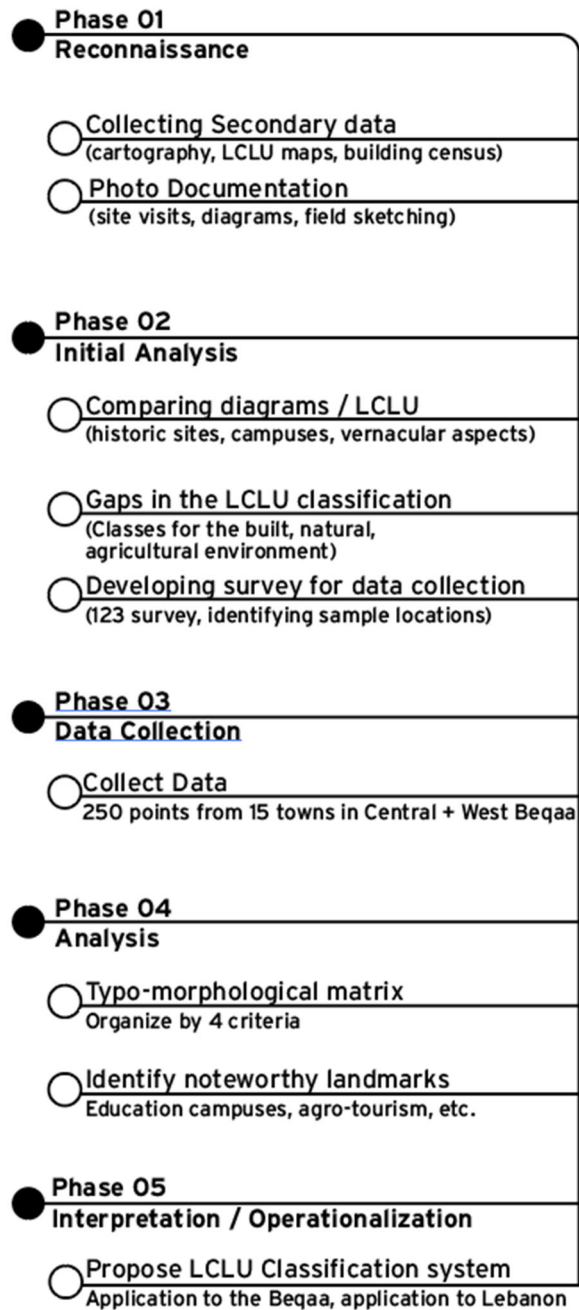


Figure 2.4: Proposed morphological study workflow.

### 3. Results

#### 3.1 Phases 01-02: Assessing the classification system of the Beqaa valley.

The Land Use Classification System crafted by the National Center for Remote Sensing Center (NCRS) for the Beqaa Valley in Lebanon is hierarchical (see figure 2.5), with 4 levels ranging in coarseness to render it amenable to different scales and study requirements. This map was generated in 2005, which means it does not reflect the few changes that took place:

1. Impacts of the July war 2006, especially the Israeli raid's destruction of the Mdeirej bridge along the Pan-Arab Highway and some cell towers, storage hangars, and other buildings and neighborhoods in the Beqaa. Since then, most of the visible damage was repaired. The war impact was addressed in later publications by staff of the NRSC (Verdeil et al., 2012b) but this did not alter the classification system addressed in this article.

2. The arrival of over 1,500,000 Syrian refugees to Lebanon, of which 320,000 approximately are registered in the Beqaa today (UNHCR, 2021). In the Beqaa, over half of the refugees dwell in tents, about 30% reside in apartments or houses shared with relatives, and the remaining live in janitor suites, agricultural rooms, or in unfinished buildings (UN Habitat & UNHCR, 2018). There is a class "Informal fabric" in the 2005 LCLU, so the refugee crisis does not necessarily introduce a new class to the system. The refugee crisis was also addressed in a publication a few years into the Syrian war (Verdeil, Faour, Hamzé, et al., 2016).

3. The completion of additional segments of the Pan-Arab Autostrad triggered some land use response (growth) along the new service roads. This also comes with the continuing growth trend of the Beqaa's built environment. This growth does not necessarily require new classes to be classified since the patterns and typologies are a replication of what is already existing.

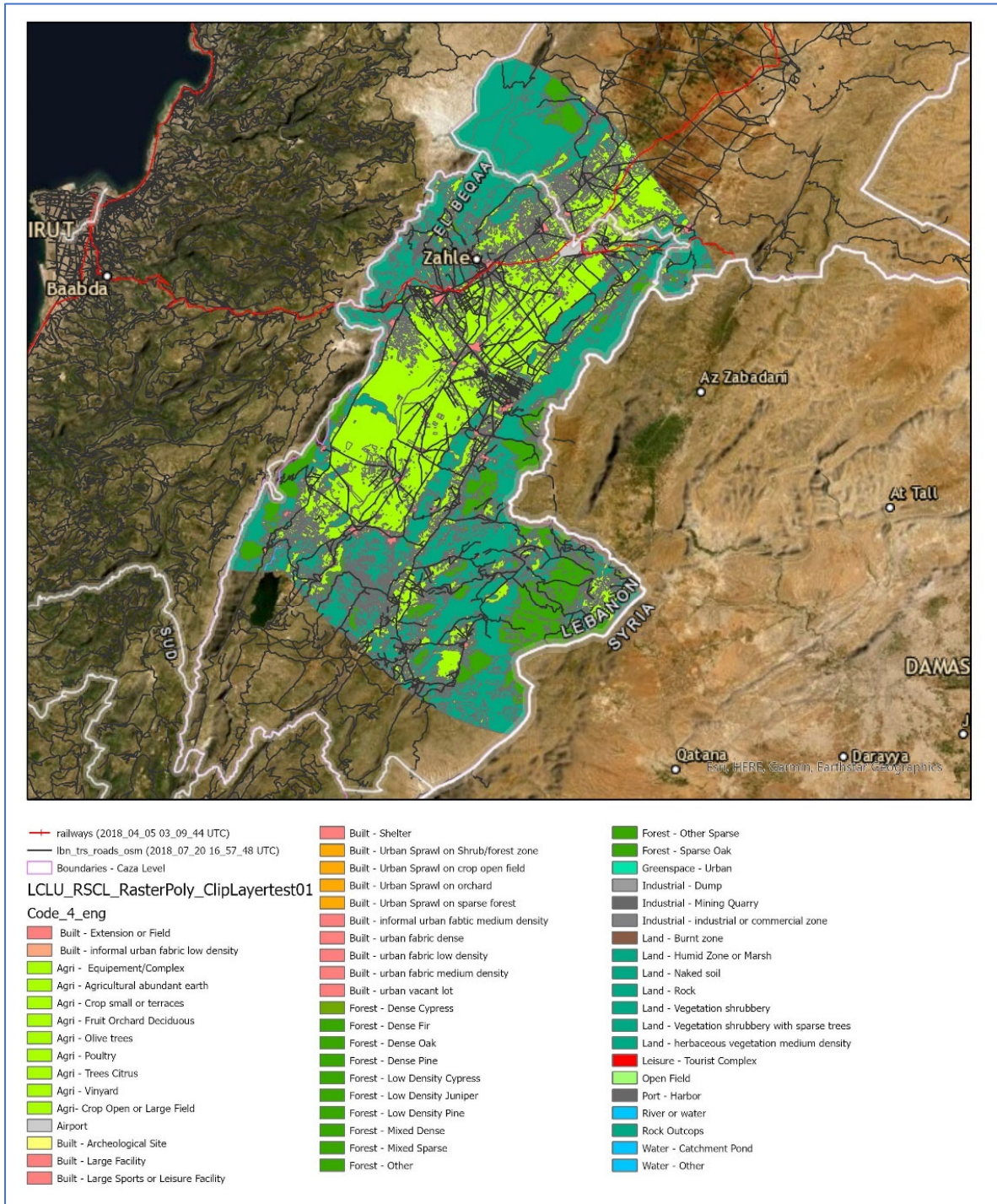


Figure 2.5. Land Cover Land Use (LCLU) classification system used by the National Remote Sensing Center.

The classification schema was originally in French reflecting a region of a 30 km buffer of the Beirut-Damascus road network, so the classes reflect uses in Central and West Beqaa and parts of Baalbeck. Land uses that are only available in Beirut, North, and South Lebanon (such as ports and coastal agricultural lands) were not considered. The hierarchy of the classes is detailed in Table 03.

**Table 03: Lebanon's 2005 National Center for Remote Sensing LCLU classification system**

Level 1	Level 2	Level 3	Level 4
Artificial / Built Territory	Urbanized Zone	Continuous urban fabric	Dense Urban Fabric
		Discontinuous urban Fabric	Urban Fabric Medium Density
			Informal Urban Fabric Medium Density
			Urban Fabric Low Density
			Informal Urban Fabric Low Density
			Touristic Complex
			Archaeological Site
		Large Facility	
	Industrial or Commercial Zone	Industrial or Commercial Zone	
	Airport	Airport	
	Artificial non-built Zone	Quarry	Quarry
		Dump	Dump
		Urban and/or Worksite Extension	Urban and/or Worksite Extension
		Urban Vacant Land	Urban Vacant Land
	Artificial green zone (non-agricultural)	Urban Green Space	Urban Green Space
		Large Sports or Leisure Facility	Large Sports or Leisure Facility
Agricultural Territory	Urban Sprawl on Field	Urban Sprawl on Field	Urban Sprawl on Field
	Field Agriculture	Field Agriculture in Large surface	Field Agriculture in Large surface
		Agriculture - Small Surfaces or Terraces	Agriculture - Small Surfaces or Terraces
		Abundant Agricultural Earth	Abundant Agricultural Earth
	Urban Sprawl on Orchard	Urban Sprawl on Orchard	Urban Sprawl on Orchard
	Orchard	Olive Trees	Olive Trees
		Vigniculture	Vigniculture
		Deciduous Fruit Trees	Deciduous Fruit Trees
		Citrus Trees	Citrus Trees
	Intensive Cultivation (market gardening,	Open Field	Open Field
Shelter		Shelter	

	small fruit, nursery...)		
	Agricultural Building	Agricultural Facility	Agricultural Facility
		Poultry	Poultry
<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Level 4</b>
Tree Cover Surface	Dense Forest	Conifer Forest - Dense	Conifer Forest - Dense
			Fir Forest - Dense (Quercus spp)
			Cypress Forest - Dense (Cyprus spp)
		Oak Forest - Dense	Oak Forest - Dense (Quercus spp)
		Hardwood Forest - Dense	Other type of dense forest (willow, poplar, plane)
		Forêt mixte dense	Mixed Forest - Dense
	Urban Sprawl on medium density forest	Urban Sprawl on Sparse Forest	Urban Sprawl on Sparse Forest
	Sparse Forest (Cover under 60%)	Sparse Conifer Forest	Conifer Forest - Low Density
			Juniper Forest - Low Density (juniperus spp)
			Cypress Forest - Low Density (Cyprus spp)
			Oak Forest - Low Density
			Other type of Sparse Forest
	Mixed Sparse Forest	Mixed Forest - Low Density	
	Urban Sprawl on Shrub Zone	Urban Sprawl on Shrub Zone	Urban Sprawl on Shrub Zone
		Shrub	Shrub
	Shrub Zone	Shrub with some Dispersed Trees	Shrub with some Dispersed Trees
Burned Down Zone	Burned Down Zone	Burned Down Zone	
Herbaceous vegetation	Herbaceous vegetation medium density	Herbaceous vegetation medium density	Herbaceous vegetation medium density
Marsh	Humid Zone or Continental Marsh	Humid Zone or Continental Marsh	Humid Zone or Continental Marsh
Natural Terrain with little to no	Bare Rock	Bare Rock	Bare Rock
	Bare Ground	Bare Ground	Bare Ground
	Rock outcrop	Rock outcrop	Rock outcrop

vegetation (non-productive)			
Water Surface	Continental Surface Water	Continental Surface Water	Continental Surface Water
	Maritime Surface Water	Maritime Surface Water	Maritime Surface Water
River	River	River	River

Upon initial analysis, a few observations:

**Sprawl is reclassified natural / agricultural landscape:** Some built environments were classified as sprawl, and more specifically the sprawl was differentiated by the type of neighboring landscapes. This was likely due to technical process that retained the original spatial polygon and reclassified it based on change. For this reason, the classes “Urban Sprawl on Orchard”, “Urban Sprawl on Sparse Forest”, and “Urban Sprawl on field” are listed as subcategories of ‘Agricultural territory’ and ‘Tree Cover’ classes. While this classification may just be a result of a non-comprehensive updating process, which could be called a technical issue, the perception of this growth is reflected in the latest edition of Atlas of Lebanon, where it is stated that urban growth in the Beqaa is considered haphazard and detrimental to the existing landscape (Verdeil et al., 2012c). While this paper will not distinguish between fabric and sprawl because that would go against the goals of the paper, there is a value in characterizing the built fabric with input from the surrounding landscapes. Baaloul, for example, is a low-density town located on the southwestern foothills of the Anti-Lebanon mountain ranges. Its buildings punctuate orchard fields and rocky slopes. Ghazza, a town comparable in size and density, is located among agricultural crops. While these two

towns are similar in terms of land uses, size, and density, their morphological profiles are quite different. The socio-economic specificities underpinning these morphological differences are beyond the scope of this paper, extending into median income, religious and political affiliation, as well as dwelling habits (Baaloul has a much larger emigrant community who built high-end villas akin to single family detached houses they only

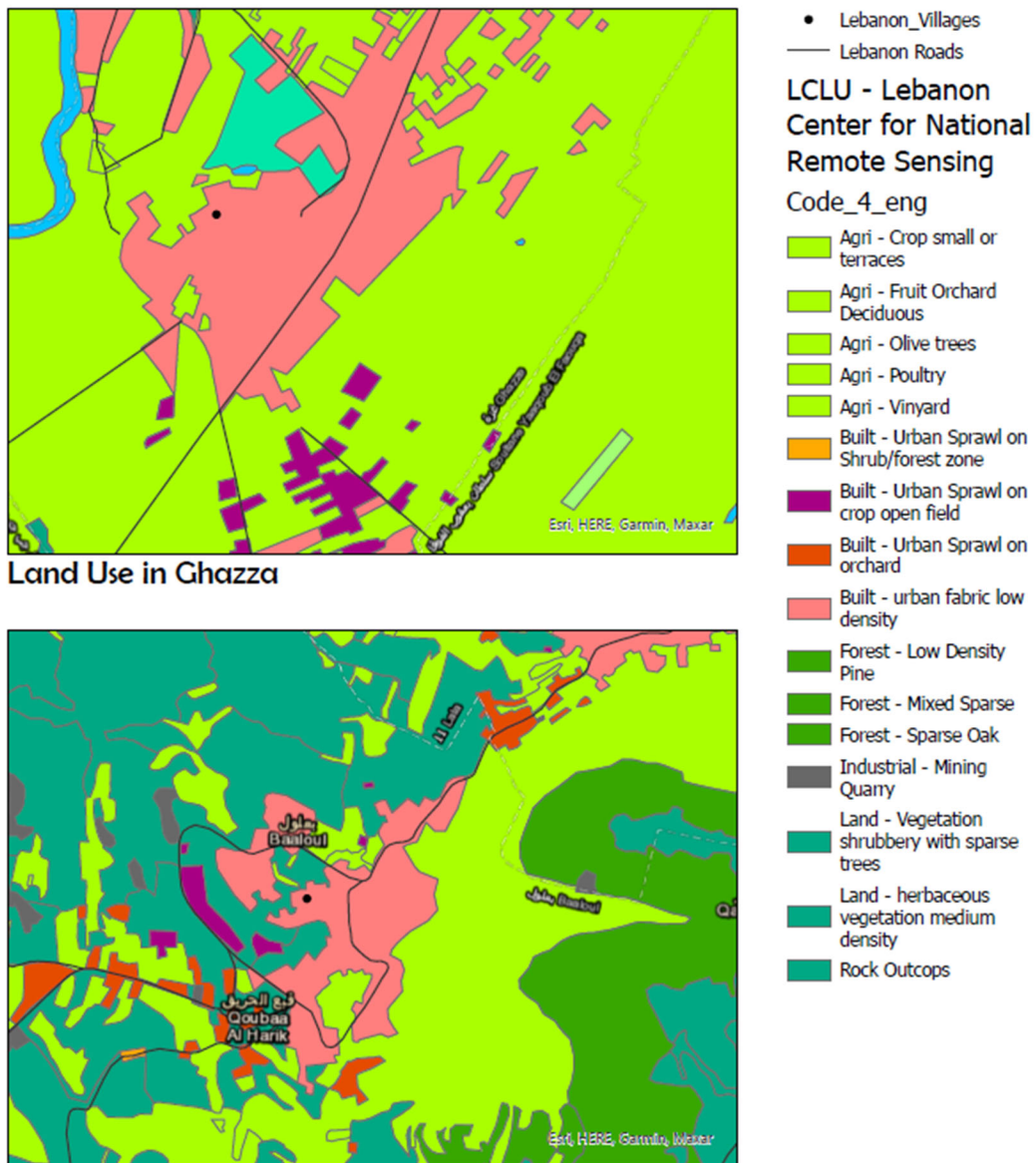


Figure 2.6: Comparison of Urban Sprawl and environs classification in Ghazza and Baaloul, Beqaa. Source: Lebanon National Center for Remote Sensing.

occu

py seasonally). However, differentiating between the two types of fabric can illustrate the built environment landscape of the Beqaa Valley.

**Density:** Classes for the built environment are distinguished as low, medium or high density at Level 04. Extracting aerial views of what these densities reflect, some fabrics are denser because of the sheer number of buildings and less space dedicated for vegetation, other infrastructure, while other locations owe their density to the number of floors predominant in buildings as well as the available, albeit limited, demographic data (Verdeil, Faour, Hamzé, et al., 2016). In 2004, there were 105,380 buildings in the Beqaa Valley of which 5,877 were constructed before 1950 and approximately 80,500 were constructed between 1950 and 1994 (Central Administration Statistics of Lebanon, 2004). Before the commercialization of the car and its availability to denizens of the Beqaa, which took place after the 1950's, the dwelling was typically constructed to house a single family. With the Islamic, Ottoman, and Roman influences on the urban patterns, the stretches of the built environment in the Beqaa constructed before the car borrowed elements adopted in other cities in the Levant, namely narrow winding streets with an interplay of 1-3 meter walls (3 to 10 ft) and semi-private spaces occasionally extending into courtyards in the center of the house (Fathy, 1973). Most of the urban fabric in the Beqaa valley was constructed after the 1950's, which then prompted the construction of new wider roads, and the retrofitting of older roads for car usage. This also meant that more apartment buildings were constructed on the fringes or gaps of existing fabric, near newly established roads, or in lands that were typically reserved for agricultural purposes.



Figure 2.7. Aerial views of different densities as classified by Lebanon's NCRS. Created with ESRI ArcGIS pro base map.

**Informality:** Locations designated as “informal” largely include small agglomerations of permanent and semi-permanent structures on the outskirts of agricultural fields, and dwelling footprints similar to Syrian refugee camps that began growing in the Beqaa after the Syrian war of 2011. These informal stretches of the urban environment would house nomadic communities that find employment in agricultural harvest and construction (Sajadian, 2020). With this class, informality is considered extraneous to the built environment, and the duality of informal/formal is implied.

**Scalar Inconsistencies:** “Large Facility” and “Large Sports or Leisure Facility” is used to designate resorts, sports facilities, and other leisure campuses located in the Beqaa, although it is important to note that not all leisure establishments were classified. Furthermore, areas equivalent in size and in specificity are not designated in separate classes. So educational establishments (Université Saint Joseph and the Lebanese

International University), large hotels (Massabki and Qadri, two large historic establishments) are not classified which creates an imbalance in the system.

Comparisons between the LCLU and the observations and diagrams collected on site revealed the following landscapes that could be considered in creating a more comprehensive classification system.

**Rail Stations:** Rail stations play a significant part in the nucleation of towns and shaping the urban growth pattern to remain within a walkable radius of the train station (Paul Oliver, 2006). Lebanon began developing its rail in the late 1880s, with support from French, German, British, and Swiss engineering input. The Beirut-Damascus rail line was the first to be constructed, crossing through Dahr el Baidar, Mreijat, Jdita, Saadnayel, Maallaka, Riyyak, and Yahfoufa towns in the Beqaa Valley (Choueiry & Maalouf, 2013). The rail shaped Riyyak as a dry port, especially with the installation of an airport in the early 1900's and later the establishment as a center for parts manufacture and engineering education. The rail ridership began dropping in the 1950's and was reduced to weekend or leisure transport. The rail ceased operations completely during the civil war 1975-1990. Today, a few towns preserved the rail stations as historic sites, but the built fabric has encroached upon the linear footprint of the rail. All things considered, the rail and the stations is an inextricable component of the built environment in the Beqaa Valley and are easy to identify in a historic heritage class.

**Infrastructural footprints:** The Pan-Arab Autostrad was conceived in the late 1940's and early 1950's to connect the Mediterranean coast to the Arab/Persian gulf. The goal for this project was to facilitate – if not increase – commuter and freight movement between Lebanon, Syria, Iraq, and the gulf countries and provide economic benefits for

all. While intermittent wars and disruptions in funding and political climate hindered this project, the Lebanese segment of the autostrada is still under construction, and a significant portion of that segment crosses through the Beqaa, connecting Dahr el Baidar to the Syrian border crossing through the towns of Bouarej, Jdita, Chtaura, Taanayel, Bar Elias, and Majdel Anjar, which aligns completely with the old Beirut Damascus road.



### Rail and Main Roads in the Beqaa



Figure 2.8: Rail and roads in the Beqaa. Produced with data courtesy of GIS/Transport Ltd and ESRI ArcGIS Pro aerial view base map.

Dilapidated bridges and rail lines are visible around the Beqaa Valley, which could be included under an infrastructure class when possible. This Designating a class for infrastructure would also be essential in future endeavors for solar energy (Dziadosz, 2018; McKenzie, 2018), and sewage rehabilitation especially for agricultural purposes (Romanos et al., 2019).

**The Slope and Income factor:** Towns such as Qab Elias, and Sultan Yaaqoub spread over two types of terrain: sharp slopes and flat terrains. On these two terrains, the character of the architecture is different. For example, smaller and older houses dressed with local stone and adorned with small yards and trees are frequently found on the slopes Qab Elias, whereas the fabric on the flat terrains shows more recent apartment buildings, less vegetation, and less stone finishing. Technological advancements were a deciding factor, since the apartment buildings are visibly more recent and constructed to house more people. This also may be due to the difference in median income and land ownership, where more people on the slopes had been residing in the town for longer and own more lands than the newly implanted apartment dweller on the Qab Elias flats. Another example is Sultan Yaaqoub. During the reign of the Ottoman Empire, it was not uncommon to use the slopes for housing since the flat terrains are more suitable for agriculture (Shami, 1989). Upon the gradual withdrawal of the Ottoman Empire in the late 1800's, many families of the Sultan began purchasing lands on the flat terrain. Seeing how cars were not yet widely available, residents opted out of doing the trip back home every day, and instead built summer sheds on the flat terrain to tend to their crops in the growing season (personal interview, S. Jaroush). Slowly these sheds grew to accommodate more people and incrementally became more permanent structures. When

cars became a commodity, the trip between the slope and the flat terrain was reduced significantly, which extended the same functionality to the slope Sultan (fawqa) and the flats Sultan (tahta). Sultan residents also pursued new career paths outside agriculture and some emigrated to Brazil and Argentina which changed land consumption patterns. This led to replacing older houses with larger apartment buildings or lavish summer homes to accommodate growing families and lifestyle changes.

**Mixed Uses:** Aside from leisure and education campuses and industrial lands, there are few built environments that have segmented land uses. Most apartment buildings are comprised of residential apartments and commercial stores on the ground floor.

**Vernacular Characters:** The local architectural character of buildings in the Beqaa is layered with French, Islamic, Italian influence. Form-based codes played a role in dictating some of these decisions, such as setback regulations and tax credits ( مكتبة زين ) 2017 (الحقوقية والأدبية, 2017) but it is common knowledge that these codes are often overlooked. Deconstructing the sources of these architectural influences and tracing the actors and circumstances that promoted, for example, modernism and post-modernism in dwellings versus the retention of aspects traditional architecture is beyond the scope of this study, but observations from this phase suggested there needs to be a distinction between typologies of dwellings.

**Education and Agri-touristic Campuses:** Université Saint Joseph(USJ), American University of Beirut Lebanese International University, and more recently the Beirut Arab University all have campuses in the Beqaa Valley. The USJ campus,

adjacent to the Jesuits convent and a preservation landscape grew to become a touristic destination in the Beqaa that includes a public park, an ecolodge, and a local restaurant.

**Developed neighborhoods:** Much like Ghana's new towns (Keeton & Nijhuis, 2019), there have been some neighborhood or subdivision style developments in Lebanon, especially near touristic areas (Glasze & Alkhayyal, 2002). While it is still unclear if large-scale developments will gain more ground in the Beqaa, there are distinctive morphological and governmental features that make this type of built environment very different from others in the Beqaa. A few examples of such developments are Houch Mandara gated community and Zone Gate in Mekseh.

**Market Typologies:** Public Markets and mixed commercial strips are another noteworthy built landscape in the Beqaa Valley . Examples of markets in the Beqaa include Qab Elias Fruits and Vegetale market, where agricultural land owners and traders display wholesale fruits and vegetables for restaurants, grocery stores, and greengrocers. Walls painted green enclose the exchange place at the center, and the walls are perforated by orange doors labeled in handwritten calligraphy with the name of the trader or trading operation. The door leads to a small space which is usually equipped with scales, some seats, and the occasional cash register. Trucks depositing or picking up the load of fruits and vegetables drive through the main entrance. This is not only a significant aspect of agricultural production in the Beqaa valley, but it is also a historic example of community-led design. The market construction was initiated by the local landowners and traders with support from the government. Another example of essential market spaces are the daily markets in towns such as Marj and Saadnayel. The market is set up in the morning under temporary structures, covering goods such as cleaning supplies,

kitchenware, clothes, dried foods, and other necessities. Malls fared well in Beirut and other coastal cities, but not as well in the Beqaa. The chain ABC, which operates many large malls in Beirut, was unsuccessful in Zahle and Chtaura. The last mall that broke ground was the Cascada Mall near 2015. The approach to the ensuring customer traffic was the installation of local anchor restaurants and creating a privately owned public park, which appealed to the masses and ensured the mall's operations despite the majority of its stores remaining vacant or closing quickly.



**View from outside the market.**  
Retail trader entrance. Traders park their cars outside the door designated with their name.



**View from inside the market.**  
Wholesale fruits and vegetables. The name of the retailer is written on the columns.

**Qab Elias wholesale Fruit and Vegetable Market**



**View from outside the market.**  
Fence and sign indicating that the market was recently rehabilitated with support from the UNHCR and the UNDP.



**View from inside the market.**  
temporary structures with cars, tarp, tables, boxes, and cables covering spreads of merchandise such as kitchenware, cleaning supplies, produce and dried goods, and clothes.

**The Marj Public Market**



Figure 2.9: Morphology of the Qab Elias and Marj markets.

### **3.2 Phase 03: Collected Data points**

500 Data points were collected from Central and West Beqaa, and a few in Baalbeck (North of Beqaa). 230 of the 500 were collected with extensive field notes and photos whereas the remaining 270 were a recording of observed land uses. All 170 points documenting the built environment were collected with extensive field notes and photos. The spatial distribution of the data points is portrayed in fig 2.10.

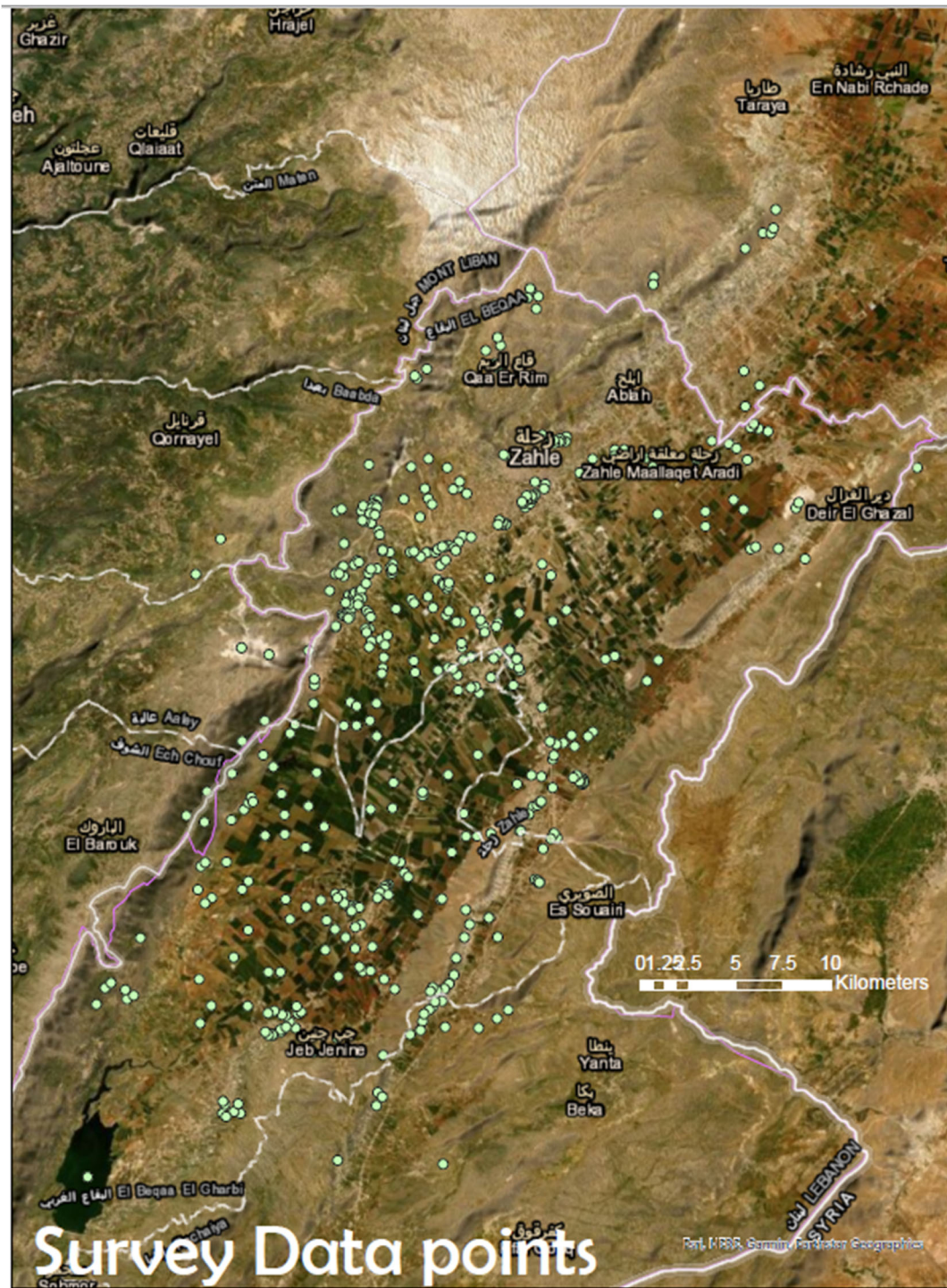


Figure 01.10: Distribution of survey data points. Points collected using ESRI Survey 123 and the map was produced with ESRI ArcGIS pro.

### 3.3 Phase 04: Typo-morphological matrix.

In line with the elements observed in urban morphological study, the building and adjacent open spaces, street grid, and fabric character were considered. Documentation collected on the field and weighed against what could be discerned from aerial view imagery since any future classification would need to be conducted on a satellite imagery ideally of a 1 meter/pixel resolution or higher (75 cm/p, 50 cm/p). The following criteria were distilled:

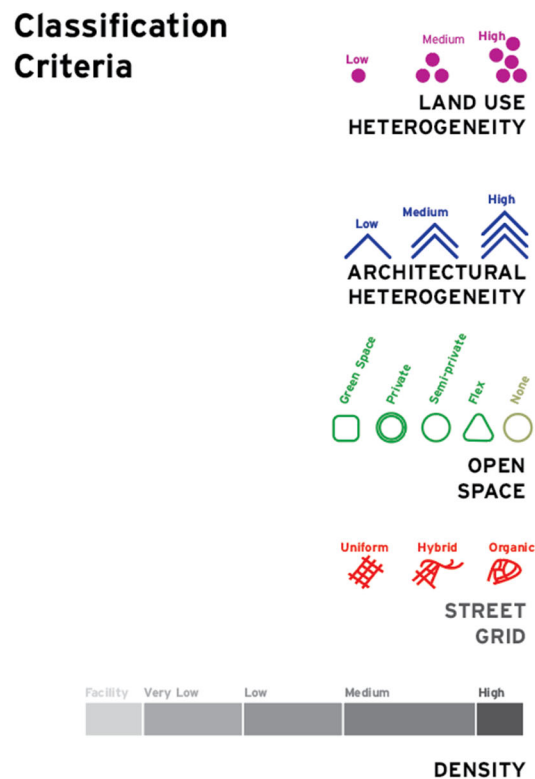


Figure 2.11: Distilled classification criteria.

**Density:** There are four categories for density, which are informed by the built / non-built proportions observed on site and in the satellite imagery and to some extent by the number of floors captured on the field (fig 2.11). To that effect and considering that the Beqaa overall remains less dense than some of the coastal cities such as Beirut, Tripoli, and Sidon, the number of floors were only used to distinguish medium density from high density. High density was only recorded in a few locations in the study. The rest of the fabric was medium density. Low density designates built environments (mostly apartment buildings) interlaced with agricultural or natural landscapes, and very low density is used to characterize villas (which house one family) and small dispersed houses. In case the landscape considered is a facility or a campus, then the term “facility” would be used to omit confusion.

**Street Grid:** The street is an essential element in urban morphological analysis, especially the character, width, and enclosure (Scheer, 2019). Since this study is intended to map streets on a larger scale, the aspect considered was the grid. Following the typologies of streets in a case-study approach conducted by Busquets et al. (Busquets et al., 2019), the closest grids to the Beqaa were the “discontinuous grid” (observed in Naples, Algiers, and Lisbon) which presented with the same irregular angles and geomorphic curves; and the “overlay grid” (observed in Damascus, Tunis, Paris), which echoed the transposition of buildings and streets in the Arab City by Fathy (Fathy, 1973). Three typologies were then used to characterize the street grids in the Beqaa: Organic, Uniform, and Hybrid. The organic street grid was mostly visible in older parts of the towns and on slopes, which dictated that roads proceed with switchbacks and attention to changes in elevation. The uniform grids were mostly observed on flat terrain with newer

construction, which complemented the larger apartment buildings and automobile circulation. Hybrid grids were visible near rivers or large curves in main roads with old and new buildings, which left irregular angles to be organized for pedestrian or vehicular circulation.

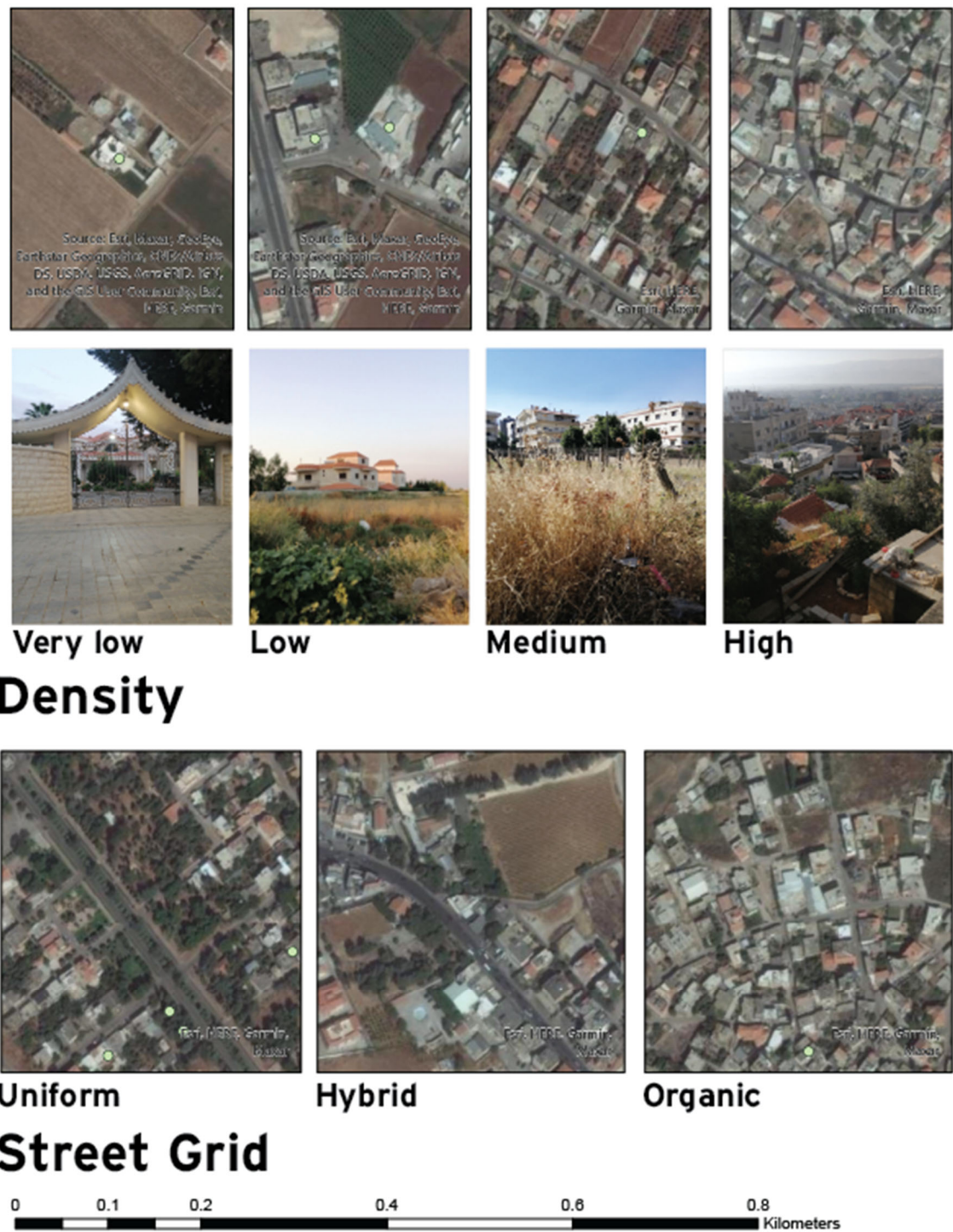


Figure 2.12: Density and street grid typologies.

**Open Space:** The nature of the open spaces between buildings dictate much about the character and the function of the town (Khan et al., 2021) especially in the Beqaa where there is a shortage of public spaces that are not commercial . Towns or parts of town where houses had semi-private spaces separated from the public realm by a 1-meter (3 foot) wall provided permeability or balance of seclusion and openness (Anjar, Bar Elias, Jdita). Villas were often surrounded with private landscaped yards, which were separated from the public by taller walls, 2 to 3 meters. On the opposite end, some buildings had an open space separating the street from the steps to the building, which could be interpreted as a place for socializing, for parking the car, or as an extension to the commercial activities taking place inside the store. Four categories of space were then identified: Private for walled-in yards; Semi-private for spaces and patios that are separated by a grade change or by a permeable wall; Flex Space for an open space that blends with the street; and Green Space for parks, commercial landscaped areas, school yards and hospital open spaces. Buildings that had no distinctive open spaces were classified as having “none” open space.

Based on morphological characteristics assessed for formal and informal environments (Kim Dovey & Kamalipour, 2018; Roy & AlSayyad, 2004) the remaining two criteria “Land Use Heterogeneity” and “Architectural Heterogeneity” were distilled. Land uses and architectural styles were considered as hard to extricate, seeing how the built fabric combines different architectural styles and various land uses in interlaced spaces. So there was no attempt to single out individual land uses or architectural styles. Instead, following the lines of “functional mix” concept, the two criteria were considered as a gradient of mixes but without attempting to discern which places are work, live, or

play/visit, since the default is most of the spaces embody all three functions. So then the criteria measured was not the function but the mixes found within the data point area. To further elaborate:

**Land Use Heterogeneity:** This would measure how heterogeneous a land use mix would be in any group of buildings. A category of ‘low’ would be used to describe industrial areas or residential villas. A category of ‘medium’ would include residential, commercial, and/or entertainment or socializing. A category of ‘high’ would include residential, commercial, and/or entertainment or socializing, in addition to civic and religious institutions or industrial. These categories were delineated for the purpose of facilitating the analysis, but the gradient of low heterogeneity – high heterogeneity can be categorized under different criteria.

**Architectural Heterogeneity:** Based on the nature of the vernacular and the informal, how the urban fabric is constructed is at best unpredictable and at worst illegible. For these reasons, a category ‘low’ would mean that all the buildings and their adjacent spaces follow the same or similar construction material, proportions, and architectural style. A category ‘medium’ would be buildings that are generally constructed with similar design parameters but that show some variations such as roof structure, size, patio space, etc. A ‘high’ category would be very different buildings (old construction, apartment buildings, unfinished inhabited structure) juxtaposed together.

Each data point collected for the built environment was classified based on the criteria, which is represented in the maps below:



Figure 2.13 Architectural heterogeneity and land use heterogeneity typologies.

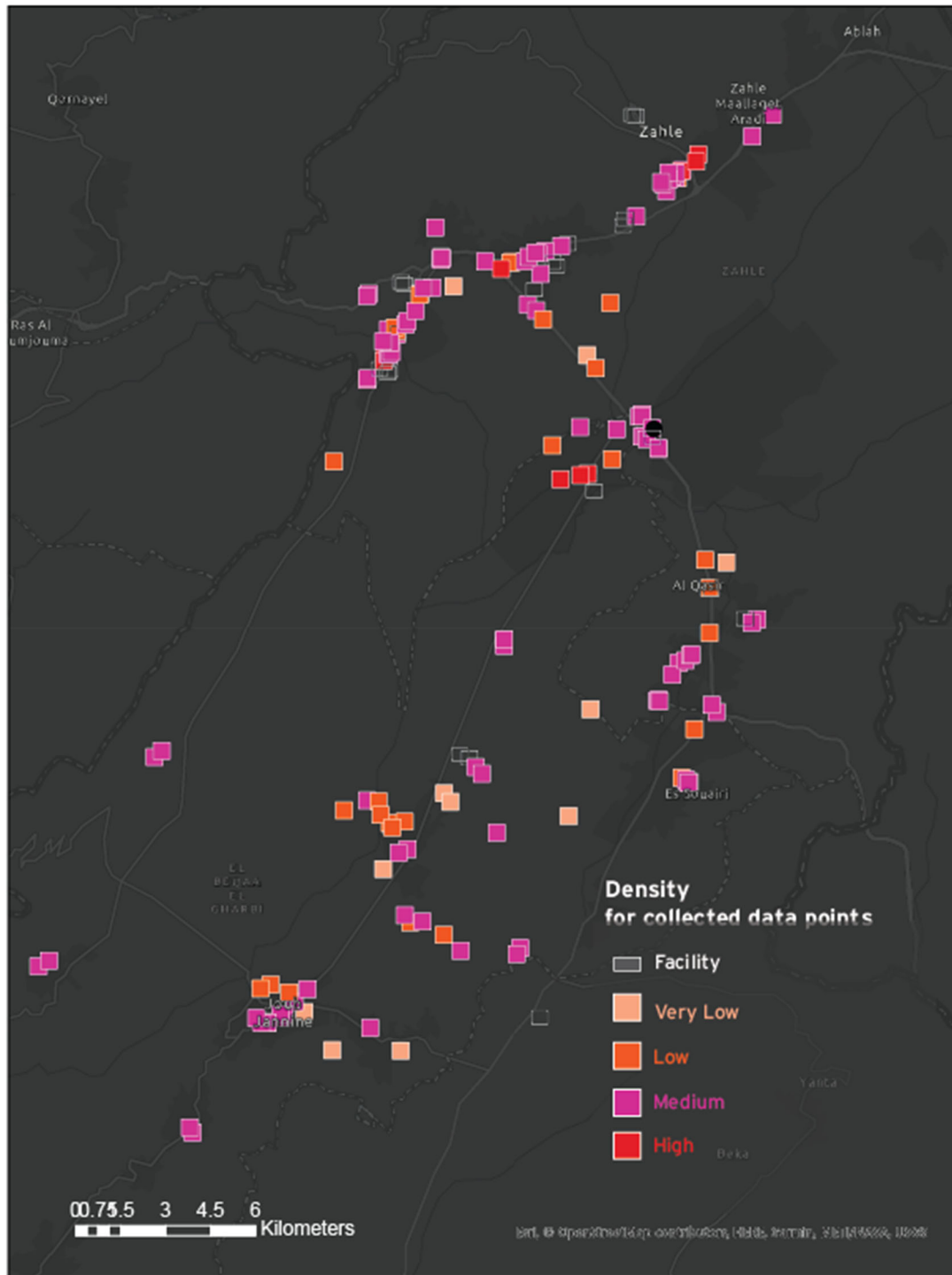


Figure 2.14: Spatial distribution of densities for the collected data points.

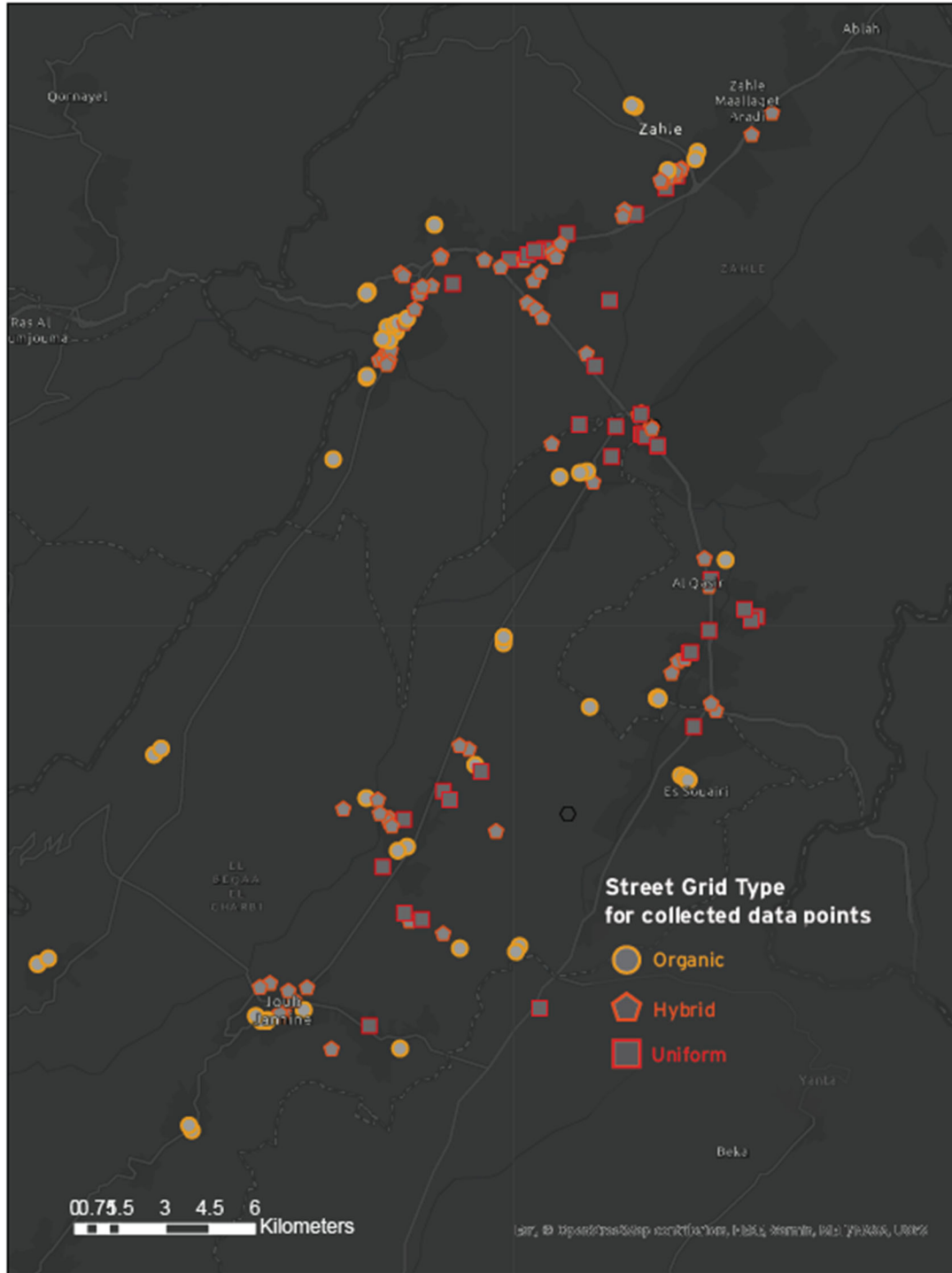


Figure 2.15: Spatial distribution of street grid types for the collected data points.

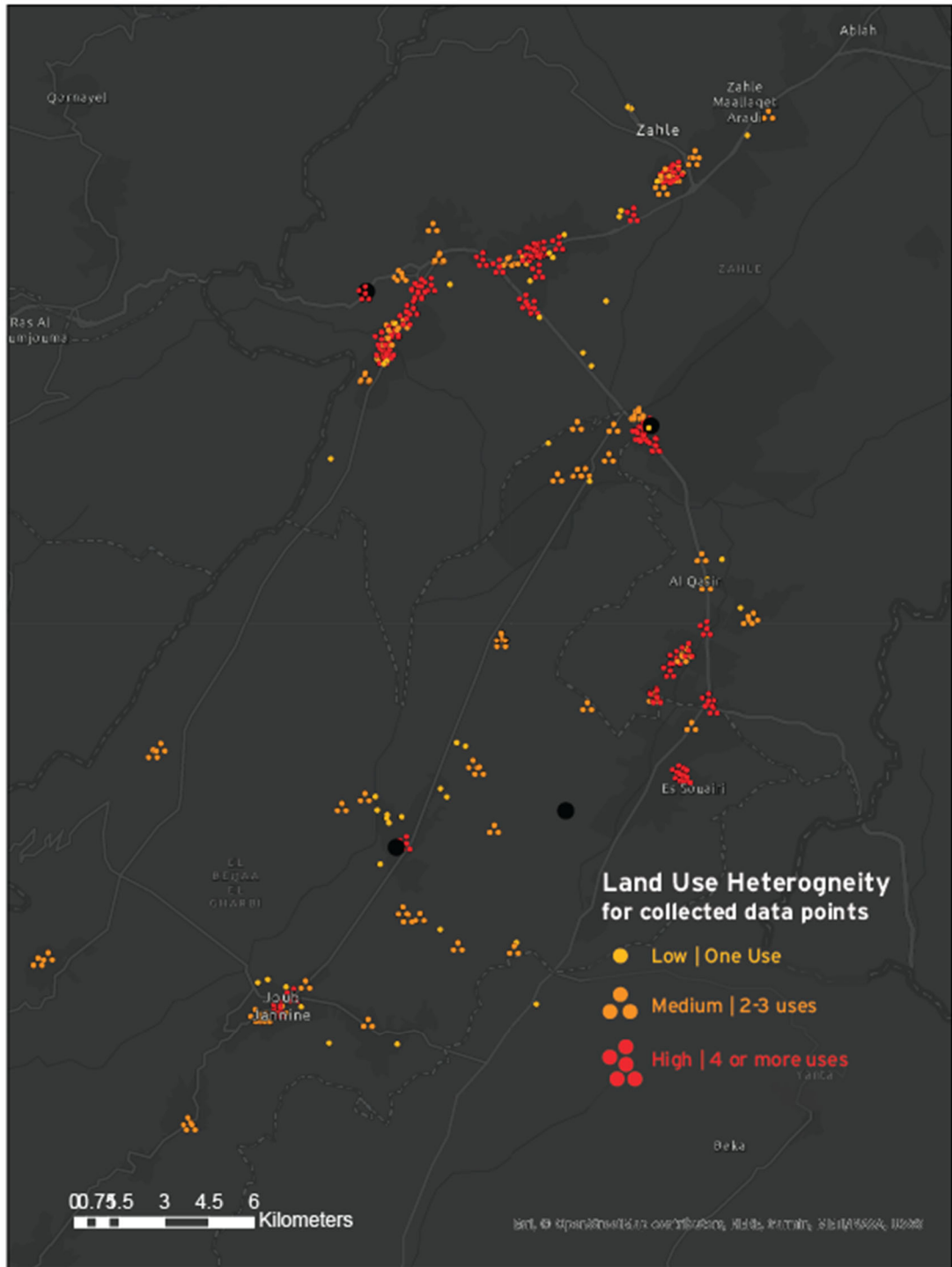


Figure 2.16: Spatial distribution of land use heterogeneity for the collected data points.

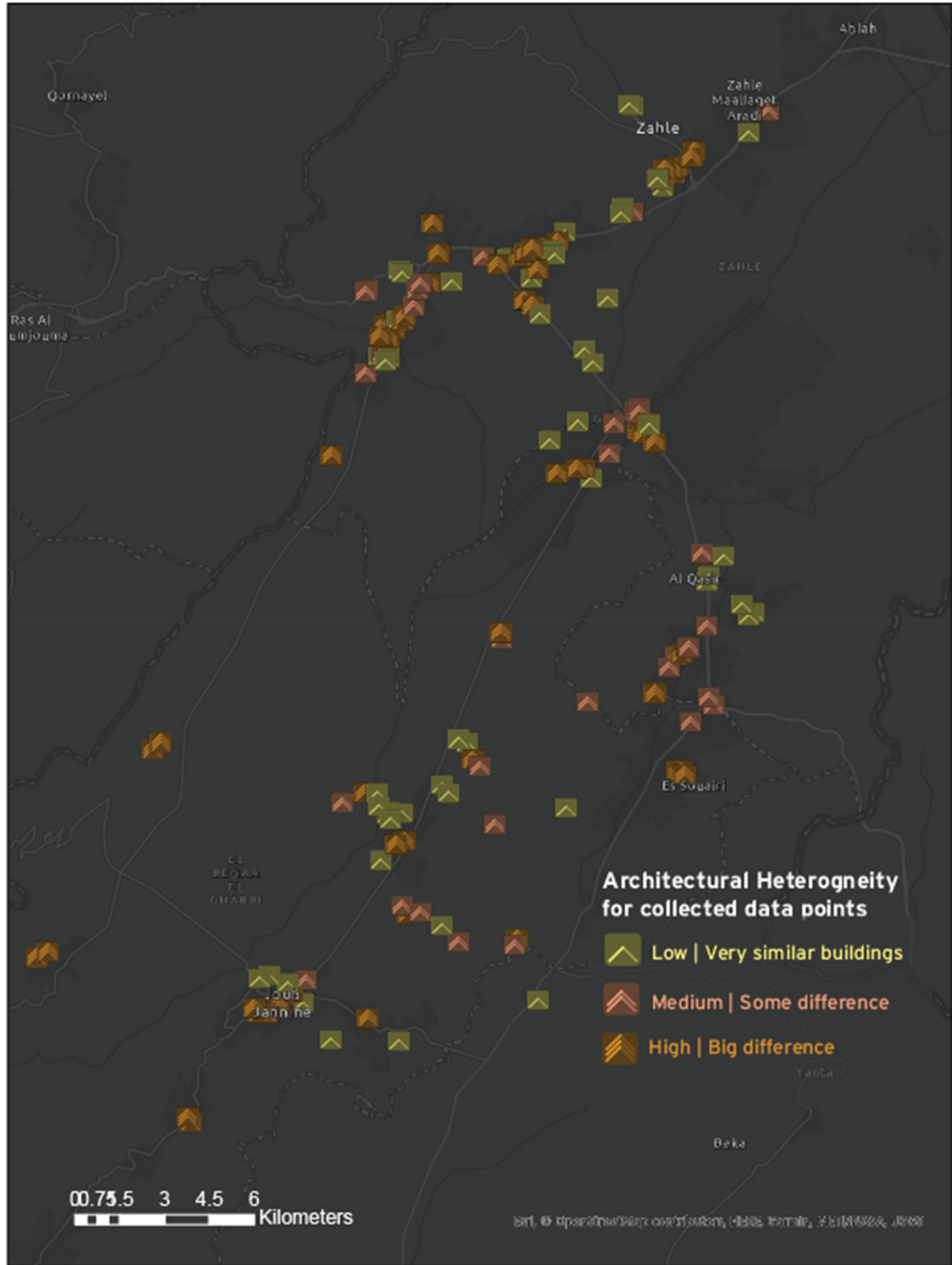


Figure 2.17 Spatial distribution of architectural heterogeneity for the collected data points.



Figure 2.18: Spatial distribution of open spaces for the collected data points.

### **3.4 Phase 05: Proposed classification system**

To translate these findings into a classification system, the data points were organized in a table by density, since it is a common denominator between this study and the NRSC of Lebanon. To maintain the hierarchy of the classification set, Level 01 was largely retained from the LCLU system with a few adjustments: “Agriculture”, “Industrial”, were retained, “Built Environment” would include all form of built structures farm buildings and industrial buildings. “Natural Landscapes” is introduced to include tree cover, marshes, and arid landscapes. “Water” would include surface water and rivers. A class “Infrastructure” was added to classify roads with large footprints such as the Pan-Arab Highway and airports.

Setting Level 01 would be an easy step to isolate the built environment data points, which are the focus of this study.

The “Built Environment” data points are then organized by the morphology criteria collected (Street Grid, Density, Open Space, Land Use Heterogeneity, and Architectural Heterogeneity), and the combinations of these criteria would inform classifications for Level 04, and then classes for levels 02 and 03 would be created based on trends. The intent was to adopt a bottom-up approach that first deconstructs the built environment to an assemblage of physical characteristics regardless of the dweller’s citizenship or social class, which goes in line with this article’s contribution to permeating the duality of informal / formal, and vernacular / planned. Fabrics that were described as haphazard, rudimentary, or informal are considered on an equal footing with what is considered legitimate.

<b>Table 04: Sample classification of the built environment by synthesis of criteria</b>						
	<b>Density</b>	<b>Street Grid</b>	<b>Architectural Heterogeneity</b>	<b>Land Use Heterogeneity</b>	<b>Open Space</b>	<b>Class_4 (proposed)</b>
Data Point 02	<b>Facility</b>	Uniform	Low	Low	Green Space	Health Facility
Data Point 03		Hybrid	Low	Low	Green space	Public Market
Data Point 05	<b>Very Low</b>	Uniform	Low	Low	Private	Villas
Data Point 06		Organic	Low	Low	Private	Villas
Data Point 07	<b>Low</b>	Organic	High	Medium	Flex Space	Developing Low Density Fabric
Data Point 08		Organic	High	High	Green Space	Developing Low Density Fabric
Data Point 09		Organic	High	High	None	Developing Low Density Fabric
Data Point 10	<b>Medium</b>	Uniform	High	High	Flex Space	Functional Mix - Town historic
Data Point 11		Uniform	High	Medium	Flex Space	Neighborhood - Apartment building
Data Point 12		Hybrid	Medium	High	Flex Space	Functional Mix - Town
Data Point 14		Uniform	Low	Medium	Flex Space	Commercial / Private Developments
Data Point 17		Hybrid	Medium	Medium	Flex Space	Functional Mix - Town
Data Point 18		Hybrid	High	Medium	None	Neighborhood - Apartment Building

Data Point 19		Hybrid	High	Medium	None	Neighborhood - Apartment Building
Data Point 20	High	Hybrid	Medium	High	None	Neighborhood - Urban
Data Point 20		Hybrid	High	High	None	Functional Mix - Urban

To facilitate the analysis, data points were organized by order of density. There are five densities: Facility, Very Low, Low, Medium, and High. This permitted the classification of “facility” densities under their functional intent (health, education, leisure). Values for the remaining physical criteria were then entered for each data point. This allowed to examine trends in commonalities between built environments and the distinctive factors between typologies. Notes, aerial views, and photos of each data point were used to inform the data entry. Data points with similar combinations of values were then identified under the same classes (Table 04). For example, all medium densities on uniform street grids with medium architectural heterogeneity and high land use heterogeneity were classified as “Functional Mix – Town”. All very low densities on organic streets with no or flex open space were classified as nomadic settlements.

**Table 05: Classification by typology combinations.**

		<b>Density</b>				
		<b>Facility</b>	<b>Very Low</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<b>Street Grid</b>	<b>Uniform</b>	By Land Use	<ul style="list-style-type: none"> <li>•Refugee Settlement</li> <li>•Villas</li> </ul>	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> <li>• Commercial Private Developments</li> <li>• Developing Low Density Fabric</li> </ul>	<ul style="list-style-type: none"> <li>•Commercial / Private Developments</li> <li>•Apartment Bldg Neighborhood</li> <li>•Functional Mix - Town</li> <li>•Medium Density Fabric - Developing</li> </ul>	N/A
	<b>Hybrid</b>	By Land Use	<ul style="list-style-type: none"> <li>•Refugee Settlement</li> <li>•Villas</li> </ul>	<ul style="list-style-type: none"> <li>• Developing Low Density Fabric</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix - Town</li> <li>• Neighborhood - Apartment Building</li> <li>• Medium Density Fabric - Developing</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood Urban</li> <li>• Functional Mix Urban</li> </ul>
	<b>Organic</b>	By Land Use	<ul style="list-style-type: none"> <li>•Nomadic Settlement</li> <li>•Refugee Settlement</li> <li>•Villas</li> </ul>	<ul style="list-style-type: none"> <li>• Historic Neighborhood</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood - Apartment and Historic Mix</li> <li>• Functional Mix - Town - Historic</li> <li>• Functional Mix - Historic Medium Density</li> </ul>	N/A

		Facility	Very Low	Low	Medium	High
<b>Open Space</b>	<b>Private</b>	By Land Use	<ul style="list-style-type: none"> <li>• Villas</li> </ul>	N/A	<ul style="list-style-type: none"> <li>• Neighborhood - Apartment Building</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood Urban</li> </ul>
	<b>Semi -Private</b>	By Land Use	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> <li>• Nomadic Settlement</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood - Apartment and Historic Mix</li> </ul>	<ul style="list-style-type: none"> <li>• Commercial / Private Developments</li> <li>• Neighborhood - Apartment Bldg</li> <li>• Functional Mix - Town</li> <li>• Medium Density Fabric - Developing</li> <li>• Neighborhood - Apartment and Historic Mix</li> <li>• Functional Mix - Town - Historic</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood Urban</li> </ul>
	<b>Green Space</b>	By Land Use	N/A	<ul style="list-style-type: none"> <li>• Historic Neighborhood</li> <li>• Commercial Private Developments</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix - Town - Historic</li> <li>• Neighborhood - Apartment and Historic Mix</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood Urban</li> <li>• Functional Mix Urban</li> </ul>
	<b>Flex</b>	By Land Use	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> <li>• Nomadic Settlement</li> </ul>	<ul style="list-style-type: none"> <li>• Developing Low Density Fabric</li> <li>• Historic Neighborhood</li> </ul>	<ul style="list-style-type: none"> <li>• Commercial / Private Developments</li> <li>• Functional Mix - Town</li> <li>• Medium Density Fabric - Developing</li> <li>• Neighborhood - Apartment Building</li> <li>• Neighborhood - Apartment and Historic Mix</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix Urban</li> </ul>

	<b>None</b>	By Land Use	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> <li>• Nomadic Settlement</li> </ul>	<ul style="list-style-type: none"> <li>• Historic Neighborhood</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix - Town</li> <li>• Medium Density Fabric - Developing</li> <li>• Neighborhood - Apartment and Historic Mix</li> <li>• Functional Mix - Historic Medium Density</li> <li>• Functional Mix - Town - Historic</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood Urban</li> <li>• Functional Mix Urban</li> </ul>
		<b>Density</b>				
		<b>Facility</b>	<b>Very Low</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<b>Architectural Heterogeneity</b>	<b>Low</b>	By Land Use	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> </ul>	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> <li>• Commercial Private Developments</li> </ul>	<ul style="list-style-type: none"> <li>• Commercial / Private Developments</li> <li>• Medium Density Fabric – Developing.</li> </ul>	N/A
	<b>Medium</b>	By Land Use	<ul style="list-style-type: none"> <li>• Nomadic Settlement</li> </ul>	<ul style="list-style-type: none"> <li>• Developing Low Density Fabric</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood - Apartment Building</li> <li>• Functional Mix - Town</li> <li>• Medium Density Fabric - Developing</li> <li>• Neighborhood - Apartment and Historic Mix.</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood Urban</li> <li>• Functional Mix Urban</li> </ul>
	<b>High</b>	By Land Use	N/A	<ul style="list-style-type: none"> <li>• Historic Neighborhood</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix - Town</li> <li>• Neighborhood - Apartment Building</li> <li>• Medium Density Fabric - Developing</li> <li>• Functional Mix - Town - Historic</li> <li>• Neighborhood - Apartment and Historic Mix.</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix Urban</li> </ul>

<b>Land Use Heterogeneity</b>	<b>Low</b>	By Land Use	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> <li>• Nomadic Settlement</li> <li>• Villas</li> </ul>	<ul style="list-style-type: none"> <li>• Refugee Settlement</li> </ul>	<ul style="list-style-type: none"> <li>• Medium Density Fabric - Developing</li> </ul>	N/A
	<b>Medium</b>	By Land Use	N/A	<ul style="list-style-type: none"> <li>• Commercial / Private Developments</li> <li>• Developing Low Density Fabric</li> </ul>	<ul style="list-style-type: none"> <li>• Neighborhood - Apartment Building</li> <li>• Medium Density Fabric - Developing</li> <li>• Neighborhood - Apartment and Historic Mix</li> </ul>	N/A
	<b>High</b>	By Land Use	N/A	<ul style="list-style-type: none"> <li>• Historic Neighborhood</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix - Town - Historic</li> <li>• Functional Mix - Historic Medium Density</li> </ul>	<ul style="list-style-type: none"> <li>• Functional Mix Urban</li> </ul>

This is not to say that each combination of criteria yields a different typology. In some cases, one typology could include more than one criteria. For example, the typology “Functional Mix – Town” includes medium and high architectural heterogeneity.

The result of this typo-morphological classification for the Beqaa Valley results in 23 classes at Level 04, which is the most detailed classification level. From there, organizing elements begin to emerge:

1. **Expressing Densities:** The element of density was a foundational element in distinguishing between different built environments. Combining it with the other criteria raised the need for more descriptive terms. As such, very low densities are expressed as ‘villas’ or ‘settlements’. ‘Town’ is used to describe neighborhoods and functional mixes of low to medium density, and ‘urban’ is used to express high density.

The terms “low density” or “medium density” are only retained at Level 04 for fabrics that are still developing (See Developing Fabric below).

2. **Facilities:** The LCLU system in use at the NRSC included a facilities class, which only included leisure and sports centers. In the studied sample, there were other observed facilities such as markets, hotels, eco-lodges, and education centers. This list is not immune to temporal impacts, especially with the growing scales of development. This list could include new types of facilities such as office parks or convention centers.

3. **The residential-only typology:** There are 3 types of typologies where only one land use occurs, which are the nomadic settlements, refugee settlements, and villas. The distinguishing difference between nomadic and refugee settlements are the street grid (the nomadic grows incrementally on organic grids with fluid boundaries whereas the refugee settlements are more planned, on uniform and hybrid grids with designated land parcels ), and the distinguishing difference between the nomadic / refugee settlement and the villa is the typology of the open space. Where villas have private green spaces such as yards, the settlements either have no open space or some flex space.

4. **Developing Fabric:** Field notes showed that some fabrics can be interpreted as on the cusp of growth. Those typically include low (1-2 floor buildings) to medium densities (2-4 floor buildings) adjacent to vacant lots, defunct agricultural lands, or construction sites. While characterizing this as “changing” or “developing” does delve into the predictive aspect of mapping, it is important to make that distinction because the nature of the imminent buildings would decide the typology the fabric belongs to. For

example, a low-density neighborhood (buildings 1-4 floors) with vacant lots can become a medium density neighborhood if more of the same buildings are installed in the empty lots, whereas it could become a functional mix fabric if larger buildings with commercial services are installed. In the unlikely event of the vacant lot becoming a green space, then it would be anchored as a low-density (town) neighborhood.

**5. Historic versus modern fabric:** Phases 01 and 02 of the study revealed the need to discern between different aspects of architectural vernacular. The overarching pre-car / post-car trend adopted to assess the street grid and the land use heterogeneity is applicable here: dwellings constructed prior to the commercialization of the car tended to house less families (1 to 2), presented aspects of traditional ‘Lebanese’ architecture, including the red tile roofs, arched windows and doors, and walls dressed with natural stone, and dwellings constructed post the commercialization of the car tended to house more families on multiple apartment floors, and either reduce or remove expensive construction material such as natural stone in favor of concrete. This is not an absolute development: many buildings constructed post-car were considered low density (such as villas) and establishments such as restaurants and eco-lodges retained aspects of traditional architecture. The proposed typologies designated “historic” built environments, which were a combination of high heterogeneity and organic grids from the remaining built fabric.

These trends and the physical criteria then shaped the hierarchy of the LCLU system. For the large and growing number of Level 04 facilities, two Level 03 facilities were created, distinguishing between “civic” (including health, public, and educational facilities) and “commercial” (including hotels, malls, and markets).

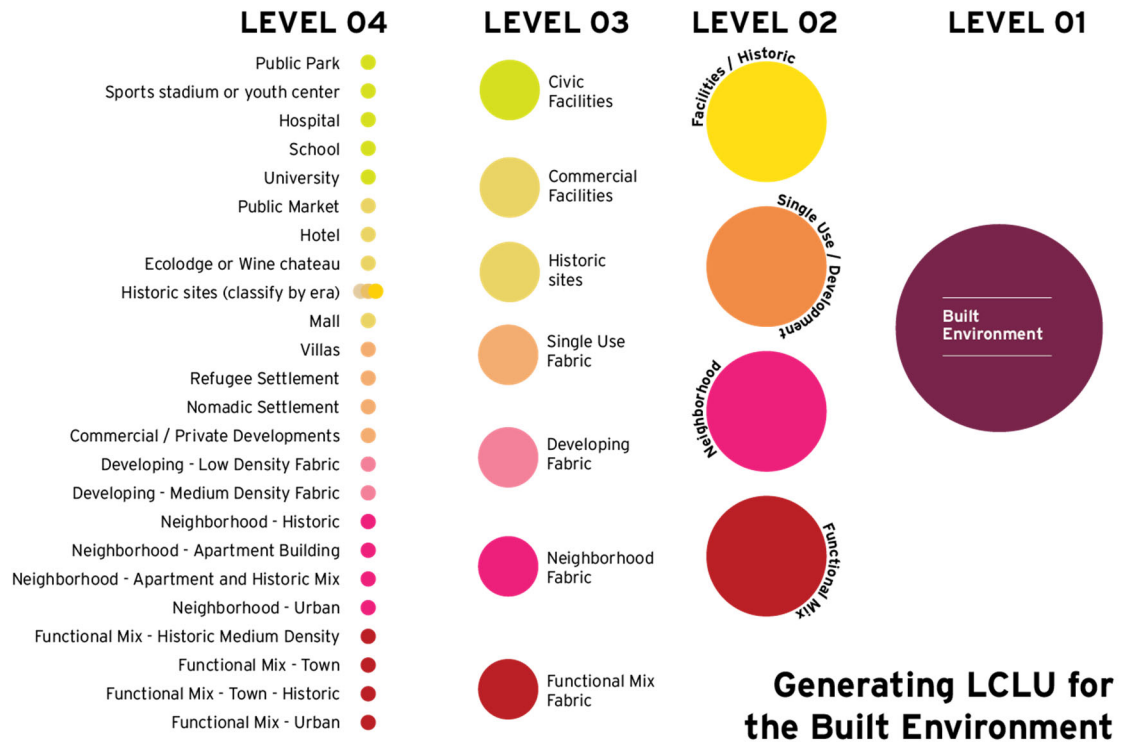


Figure 2.19: Proposed hierarchical LCLU classification for the built environment

The class “single use fabric” is introduced for strictly residential fabrics including settlements, villas, and planned neighborhoods. The class “Neighborhood Fabric” is designated for fabrics that are primarily residential but mixed with the usual assortments of small businesses such as bakeries, pharmacies, hair salons, and offices. The “Functional Mix Fabric” is introduced for fabrics where the ratio of businesses/services to residential dwellings exceeds that of the “Neighborhood Fabric”.

Level 02 classes would then be “Facilities”, “Single Use Fabric”, “Neighborhood”, and “Functional” mix, which would be gathered under the Level 01 class “Built Environment.

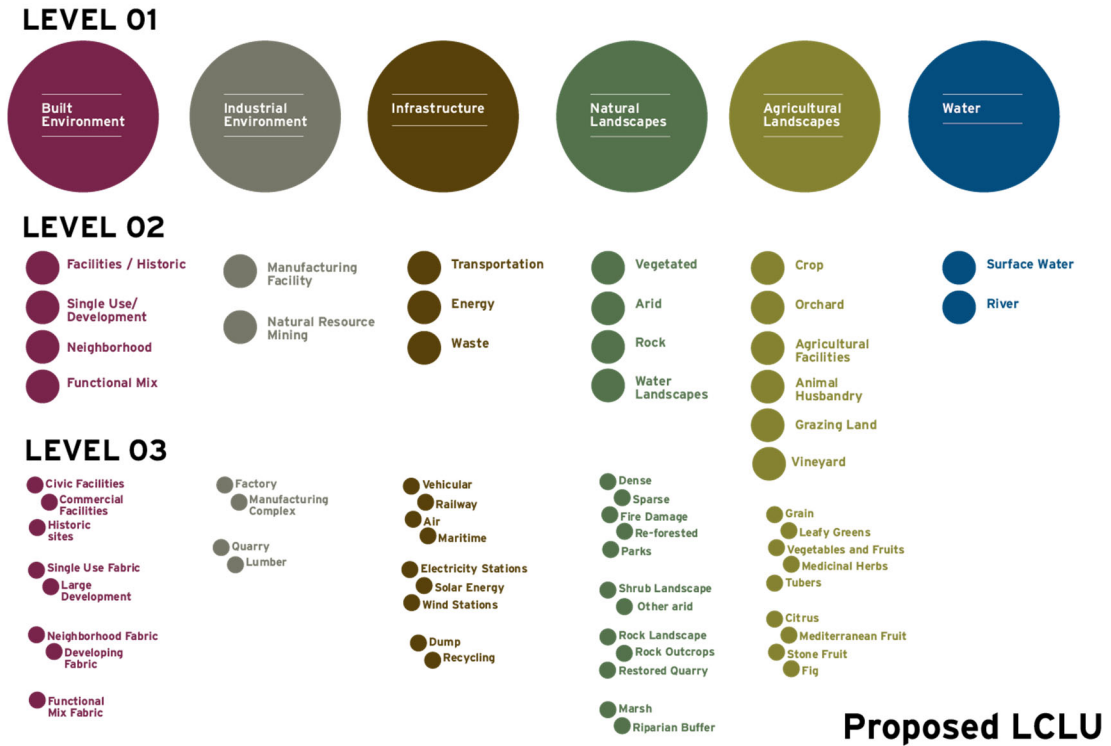


Figure 20.20: Proposed hierarchical LCLU classification.

At a larger scale and considering other observations from the field, the following changes could be expanded to other classes. “Industrial Environment” would be its own Level 01 class, which would include mining (quarry, lumber, or other) and manufacturing (light industry, food industry, clothing, and other). “Infrastructure” class would include transportation (vehicular, air, maritime, and rail) which could be further classified as operational, under construction, or defunct. “Natural Landscapes” would not distinguish between “shrub” and “forest” at Level 02, because plants tend to live in diverse

communities (Rainer & West, 2016), and there are other functional characteristics that are more productive such as density and health, especially with the recent wildfires that ravaged Lebanon and the landscape restoration initiatives (Litani River Authority cleanups and the Lebanon Reforestation Initiative) that were initiated in the past decade. There is a definite value in characterizing and classifying the various plant communities, which could be done at Level 04 (Pinus pinea community, Cedrus libani community).

#### **4. Conclusion**

This article proposed typo-morphology, an essential toolkit in urban morphological research and vernacular architecture study, to create an LCLU classification system specific to the vernacular and informal built environment in the Beqaa valley, an area deprived of spatial data and that is also often overlooked in regional planning initiatives.

The proposed workflow in this article is transferable to other rural or small town regions especially if the built environment is informal or vernacular. This method focuses on deconstructing and understanding the commonplace architecture of the urban environment, which is the outcome of human actions and behaviors (Carter & Collins Cromley, 2005) in their aspiration to navigate the constraints placed upon them by their economic, social and environmental circumstances while also aspiring towards modernity (N AlSyyad, 2014). This deconstruction distills criteria of the built environment that are used to identify typologies of the built environment that can then inform LCLU classes for remote sensing. Furthermore, it is in line with the fifth avenue for morphological

studies, the design-oriented approach, which aims to assert and preserve region-specific character to better position it for comparative studies.

The spatial knowledge related to urban planning that this approach can yield is a more comprehensive portrayal of the built environment condition in the Beqaa valley outside the labels of ‘haphazard’ or ‘illegal’ which seem to cause gridlock due to the government’s inability to consistently govern and regulate. To provide an example: if there was an intention to create a continuous multi-modal transportation corridor connecting the towns of central and west Beqaa, this classification can identify the concentrations of high density neighborhoods (Neighborhood – Urban, Neighborhood – Town) to inform the alignment of rail stations and planning for transit routes to fulfill the first and last mile. Fabrics that present abundant surfaces of flex space can be considered suitable building bike and pedestrian routes connecting neighborhood fabrics to functional nodes and rail stations. Another example is should Beqaa’s authorities aim to identify critical areas for historic preservation efforts, this classification system can help identify fabrics with the highest levels of architectural heterogeneity and precise locations of heritage sites for a comprehensive plan.

Limitations of this study stem from the sample size used to classify the fabrics of the Beqaa. Undoubtedly, more samples from towns in South Beqaa and further north would eliminate any imminent redundancies. Comparisons with land classes on coastal cities would also make for a more functional classification system to be used in Lebanon. Deeper knowledge of the architectural history in the Beqaa valley would also be helpful in understanding the inner mechanics of the built environment, specifically the

juxtapositions of traditional and modern styles of building as well as information about dwellers and economic status.

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**ARTICLE 03: CLASSIFYING BUILT ENVIRONMENTS FOR  
TRANSPORTATION CORRIDORS USING OBJECT-BASED IMAGE  
ANALYSIS (GEOBIA) IN THE BEQAA VALLEY, LEBANON <sup>3</sup>**

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<sup>3</sup> Lynn Abdouni, *Journal of Spatial Science*, to be submitted.

## **Abstract**

This article implements a hybrid workflow, which is a combination of supervised and unsupervised classification processes for mapping the built environment of the Beqaa Valley in Lebanon. The workflow complements Very High Resolution PlanetScope Multispectral satellite data and ancillary datasets with ground truthing information to overcome the semantic gap – the difference between the character of the built environment and its map – in producing meaningful regional maps. The methodology is based on Geographic Object-Based Image Analysis (GEOBIA), leveraging texture (Grey Level Co-Occurrence Matrix Contrast), brightness, and shape aspects for segmentation and classification processes to classify a region with low access to spatial data using a classification system generated from ground-truthing data. Results show high levels of accuracy for classification on Level 01, which distinguishes between built, agricultural, infrastructure, natural landscapes and water. Results show lower levels of accuracies for Level 02, which strives to distinguish between built environment subclasses (neighborhood, functional use, villas,). Advantages and limitations of the workflow in comparison with other Land Cover Land Use (LCLU) maps are discussed.

### **1. Introduction**

Land Cover Land Use (LCLU) maps are a form of spatial data highly utilized to inform regional urban planning research and policy as well as environmental planning, forestry, ecology, transportation planning, and disaster mitigation. LCLU data typically prioritizes regional ecological concerns such as vegetation health, agricultural systems, water quality, and disaster impacts. On a more local level, LCLU maps are

complemented with other data such as population, transportation, zoning to decode the multiplicities and complexities of urban dynamics and generate forecasts for upcoming changes. Otherwise, the urban environment in LCLU maps is characterized with minimal detail and is restricted mostly to the context of larger cities.

LCLU maps are generated by relying on classification systems. Classification systems are the sum of classes or categories used to interpret imagery, often created as a hierarchy ranging from coarse to detailed. The level and nature of detail are driven by scale and the purpose of the map. The expression of scale and classification systems is intuitive: larger areas are classified more generally, whereas smaller areas are typically classified more specifically. For example, agriculture fields in a global scale are categorized under “agriculture”, under “orchards or crops” on a national scale, then under “stone fruit orchards, citrus, vineyards, grains, leafy green, tobacco” on a local scale. The purpose of the intended map also drives the classification system. If the intended map is to chart the distribution of agricultural lands, there will be more numerous and specific classes to delineate the various crops opposite a few classes for the built environment. Broad, coarse, and general land use/land cover classification systems include the International Geosphere-Biosphere Program IGBP Land Cover Classification System (Loveland et al., 1999), the U.S. Department of the Interior Fish & Wildlife Service Classification of Wetlands and Deepwater Habitats (Wetlands Subcommittee, 2013), the U.S. Geological Survey Land-Use/Land-Cover Classification System (J. R. Anderson, 1976), the U.S. National Vegetation and Classification System and the COoRdination of INformation on the Environment (CORINE) deployed in 1985 to systemize land use and land cover mapping in the European Continent (Kosztra et al., 2017). These systems are

concerned with characterizing the land cover (vegetation, soil, water, paved) to generate the spatial knowledge necessary for preliminary or regional research. Depending on the field of study, it may be complemented with local datasets, Light Detection and Ranging (LiDar) data, and others. In urban studies and urban planning, more specific classification systems are in use such as the American Planning Association Land-Based Classification System (American Planning Association, 2001).

Recent efforts in producing LCLU maps are increasingly shaped by the need to map overlooked landscapes such as informal settlements (Kohli et al., 2016; Kuffer et al., 2020) and the need to create unified and frequently updated maps, exemplified in ESRI's latest global Land Cover Map (*Esri 2020 Land Cover - Overview*, n.d.). Balancing these two needs requires classification processes that are computationally affordable and that can easily integrate local knowledge to represent the landscapes specific to the area of study.

The information communicated by LCLU maps is typically presented in classes, or categories that describe the land. There is a distinct difference between Land Cover and Land Use: while land cover maps typically characterize morphological mineral objects (buildings, roads) and natural objects (vegetation, water, rocks), land use maps denote the usage from an anthropocentric perspective (agriculture, residential, commercial, industrial, conservation). Land Cover is descriptive of the landscape form, whereas Land Use is either inferred or dictated by other sources such as zoning maps or policies. With the increasing sophistication of geospatial analysis software and the quality of the satellite imagery, there are multiple efforts to create more descriptive maps, and those are often equated with a shift in focus of these maps from a land cover centric

paradigm towards indicators of “land use”(T. Blaschke, 2010). These efforts have led to a confusion between the two (land cover and land use) and took away from the consistency and uniformity of LULC data (Weng, 2014).

### **1.1 Land Cover Classification Processes**

Capturing photos of the landscapes we live in from space began in 1946 by attaching small cameras to V-2 rockets fired from the White Sands Proving grounds in New Mexico. Since the 1950’s, imagery was collected by a growing number of spacecraft, such as rockets, ballistic missiles, large satellites, and manned spacecraft (Lillesand & Kiefer, 1987b), and more recently commercial and small satellites (Kramer & Cracknell, 2008). This growth yielded a steady increase of the quantity (data sources) and quality (spatial resolution, temporal resolution, spectral resolution) of the data that is becoming more accessible or affordable. This growing abundance of data, compounded by ongoing innovation in analysis methods meets global needs for secure data-supply (Belward & Skøien, 2015). Very High Resolution (VHR) multispectral imagery is considered as imagery with a resolution of <5 meters/pixel (each pixel on screen represents 5 meters or less on the ground), and is typically comprised of 4 bands (Red, Green, Blue, Near Infrared). Classification of data from satellite imagery is described as the action of extracting actionable information designed for specific purposes such as management of ecosystems and urban areas, studying land changes, and monitoring natural and anthropic phenomena (Briottet et al., 2016). In this process, it is important to note the difference between ‘information’ classes, which are classes or categories defined for the purposes of the analysis and ‘spectral’ classes are those inherent in the remote

sensor data, which need further processing to become legible and useful for the analysis (Campbell, 1983).

The numerous methods of classification fall under two large umbrellas: supervised and unsupervised. Supervised classification assumes a previous knowledge of each information class's spectral properties and adopts training sets to directly assign each pixel or object under one of these information classes. Unsupervised classification, on the other hand, is based on 'natural' groupings of spectral properties of pixels. After pixels or objects are clustered in groups, information classes are assigned to each cluster (Jensen, 1986b). Image classification approaches are numerous and span over multiple types of a priori or a posteriori classifiers including but not limited to Maximum Likelihood, Artificial Neural Network, Decision Tree, Random Forest, Support Vector Machine, fuzzy-set, Iterative Self-Organizing Data Analysis Technique, and K-means and are today often used in combination to improve the accuracy of the classification process (Lu & Weng, 2007). With the increase of spatial resolution of satellite imagery, the pixel became finer and representative of a smaller geographic area, one object could be comprised of multiple pixels. This meant that the pixel is no longer a productive unit of analysis, which in turn gave way for the Geographic Object-Based Image Analysis Techniques as an emerging paradigm (Thomas Blaschke et al., 2014).

## **1.2 Geographic Object-Based Image Analysis (GEOBIA): Segmentation and Classification**

Object-Based Image Analysis (GEOBIA, or OBIA) can be defined as “a sub-discipline of GIScience devoted to partitioning remote sensing (RS) imagery into meaningful image-objects and assessing their characteristics through spatial, spectral and temporal scale” (Hay & Castilla, 2006). Image objects are entities representative of scene components and entities distinguishable in an image (Thomas Blaschke et al., 2014).

In breaking down the satellite image into objects, GEOBIA employs a variety of spatial, spectral, and contextual segmentation and classification processes to extract built, natural, and agricultural features. Segmentation is the action of separating areas of homogenous properties, resulting in objects with distinct spectral and geometric characteristics (Kettig & Landgrebe, 1976). The resulting objects can then be assigned to information classes based on their spectral properties, landscape metrics, texture, brightness, relationship to other objects, or geometric characteristics (Herold et al., 2002; Yuan et al., 2014). Using a combination of these characteristics to perform multiple segmentations and assignments is common especially when decision trees are used (Khatami et al., 2016) and when objects belonging to the same information classes exhibit different spectral, texture, brightness, or geometric properties (Briottet et al., 2016).

While early research in GEOBIA comprised of two steps, segmentation followed by classification, today’s object-oriented analysis (OOA) workflows are more complex and consider objects not only used as representation of information but as process objects in a cyclical and iterative extraction guided by expert knowledge (Baatz et al., 2008).

Hossain and Chen elaborated on 4 examples of such workflows: pixel-based, edge-based, region-based, and hybrid segmentation methods (Hossain & Chen, 2019) for OOA. Pixel-based OOA techniques identify thresholds to separate objects, which is useful for extracting buildings, trees, and infrastructure, if the resolution of the imagery is very high (<1m) (Song et al., 2019) but is also applicable to discern different landscapes on a global scale (D'Oleire-Oltmanns et al., 2011). An edge-based approach delineates a boundary between objects or pixels with pronounced differences in spectral, grey, or index values and employs contouring algorithms to fill in the gaps between the segments and then determine the object enclosed (Kaganami & Beiji, 2009; Shih & Cheng, 2004). Region or area-based segmentation methods assume that pixels enclosed within the same region have similar values and apply a combination of splitting, merging, and growing processes to extract features (Benz et al., 2004; Tremeau & Borel, 1997). Hossain and Chen described hybrid segmentation methods as processes that integrate edge-based and region-based techniques as an effort to overcome the limitations of both. By the same logic, hybrid methods can be expanded beyond the scopes of these two techniques to integrate pixel-based techniques and integrate ancillary thematic data such as streets (Kindu et al., 2013; Yılmaz et al., 2019), parcel and building footprints (Zhou & Troy, 2008), waterways and conservation polygons to speed-track the classification process. When available, ancillary thematic data identify known entities in regions, towns, and cities, with little or no access to geospatial data, which reduces the numbers of iterations needed to distinguish the remaining built and non-built objects.

### **1.3 Overcoming the Semantic Gap in Regions with Low Access to Spatial Data**

Smeulders et al. defined the semantic gap in image analysis as ‘the lack of coincidence between the information that one can extract from the visual data and the interpretation that the same data have for a user in a given situation’ (Smeulders et al., 2000). The semantic gap is especially palpable in areas where access to accurate geospatial data is not always available. While automated and semi-automated processes to produce LULC maps are a viable option to provide access to geospatial data, LULC classification systems used to generate these maps are either too coarse or not representative of the study area. Regions with low access to geospatial data are prevalent in the Global South, specifically regions that are outside the main cities (Fonte et al., 2017).

An illustrated example of underexplored and spatially underrepresented landscape is the informal settlement. To create LULC maps that represent informal settlements, attention to the pattern and texture of the built environment facilitates the distinction between informal settlements and other urban fabrics. Techniques such as Multiple Kernel Learning (Gevaert et al., 2016), Convolutional Neural Networks (Mboga et al., 2017), leveraging the Grey Level Co-Occurrence Matrix (Kohli et al., 2016) and de-siloing mapping approaches to include citizen science and ancillary data sets (Kuffer et al., 2020) are some methods employed to extract features such as buildings, impervious surfaces, vegetation, and others to in turn discern between the different urban fabric typologies. Such site-specific approaches grapple with the unique spectral and geometric characteristics of the study area and inform more inclusive and representative LULC maps.

In the case of the Middle East, spectral signatures for vegetation, built, and cultivated landscapes are often different from those specific to the Global North, rendering indices such as Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) of little use. Reflectance criteria, which is the amount of light reflected from the surface, is typically used to extract urban features such as roofs, and paved surfaces. In the case of regions with loosely enforced or absent urban codes, this criteria has limitations when using publicly available VHR satellite imagery (3 m/pxl) due to the irregular pattern of overlapping roofs and the different materials used in the construction of the buildings.

. To bridge that gap, expert knowledge – summarized as the knowledge of the underlying data and software processes along with uncertainties of these processes, and an understanding of the context and hierarchies of the problem or the research question (Benz et al., 2004) – are essential to the production of LCLU maps.

To elaborate further on understanding the problem with the research question, object ontology, which is the explicit depiction of a conceptualization or a diagrammatic abstract view of the world represented for a particular goal (Durand et al., 2017; Gruber, 1995), emerges as a critical keyword that facilitates the application of OOA's in the production of LULC maps. A recent definition of 'Ontology' describes it as the science of what is, the kinds of structures and objects, properties in every area of reality by seeking the definitive and exhaustive classification of entities in all spheres of being (Smith & Welty, 2001). The application of ontology in GIS and Remote sensing is, intuitively, in the action of extraction of information in different stages of classification (Fonseca et al., 2002). Methodologically, ontology in OOA's for creating LULC's is

manifested in the construction of the classification system (Puissant et al., 2017), linking real-world concepts to the objects, connecting qualitative data (vegetation aspects) to quantitative data (spectral signatures)(Arvor et al., 2013), and assessing the appropriate scale for Minimum Mapping Units, which are the size of the smallest object that can be reliably represented in any mapping process (K. Green et al., 2017). In essence, a GEOBIA approach to generate LULC maps provides many advantages and can integrate expert knowledge.

## **2. Data**

### **2.1 Study Area**

The Beqaa Plains are situated between the Mount Lebanon and the Anti-Lebanon ranges. Largely peri-urban and rural, their surface area is approximately 500 square miles (1300 km<sup>2</sup>), with 800-1200 ml of rainfall and fertile soil. Crop and fruit production from the Beqaa accounts for about 45% of Lebanon's agricultural sector production(Verdeil, Faour, HamzeMÍ, et al., 2016). In terms of landmarks, the Beqaa has historic sites dating back to the Phoenician (2500 B.C.), Roman (27 B.C.), Umayyad (661 A.D.) , and Ottoman (1500) eras as well as the French mandate (1923). Prior to Lebanese independence in 1943, most of the Beqaa'i territory was part of Syria. Along these influences, the present organization of landscapes in the Beqaa is driven by two main aspects. First, its agricultural and light industry sectors, and the Beirut-Damascus Road network, which previously included a rail line. The early footprint of the Beirut-Damascus Road network was anchored toward the end of the Ottoman Empire and French investments into reducing the trip from Beirut to Damascus from its approximate

4 days to a mere 12 hours (Harris, 2012). Lebanon's coast sports some of the oldest continuously lived environments in the world. Historic centers of coastal cities develop into high density urban fabric, and the boundaries of these cities incrementally expand along the coast and inland territories. The evolution and growth patterns of coastal cities are evident in architectural trends and are also spatially documented. The Beqaa's growth pattern is different: other than two mid-size cities (Zahle and Baalbek), its towns and villages were originally rural and housed agricultural landowners and workers. Towards the end of the Ottoman Empire, French investors began the groundwork on engineering the Beirut-Damascus main road that cuts through the Beqaa Valley. The road was to reduce the trip between the capitals Beirut and Damascus from a few days to under half a day. The road was complimented with a heavy rail line, which was operational between the late 1890's until the late 1970's. The sharp increase in traffic fueled and shaped much of the urban growth in the Beqaa Valley, and attracted the patterns towards the footprint of the Beirut-Damascus road network. Results of the classification process would shed light on the distribution of built and non-built landscapes near the Beirut-Damascus transportation corridor. While the paper describes the classification system used for the Beqaa region, the proposed classification process would focus on the flat plains of the Beqaa and will not delve into use the flanking slopes of the Mount Lebanon and Anti-Lebanon ranges.

## 2.2 Data Sources

The following data sources were used to classify the study area:

- **Planet Scope Imagery:** Very high-resolution 3M (VHR) 4-band Multispectral (R, G, B, NIR) extracted from August 2019 for their 0% cloud cover and highest coverage.
- **Ancillary datasets:** polygon layers for 1) road and rail networks; 2) rivers and natural conservation areas ; and 3) Topography were obtained from the Remote Sensing Center in Lebanon and private geospatial consulting firms. It is important to note that Open Street Maps (OSM) would be a very useful resource, but upon comparison, the street network obtained from geospatial consulting firms was more populated than the most updated OSM dataset for the Beqaa.
- **Ground truthing data:** 500 data points were collected via ArcGIS survey123 (Esri, 2018), which is available in a web platform and a mobile application, used to collect data by designing a specific survey. Data points included site observations, age of building, and land uses as well as photos. Data points were used generate the classification system classes and serve for ground truthing.

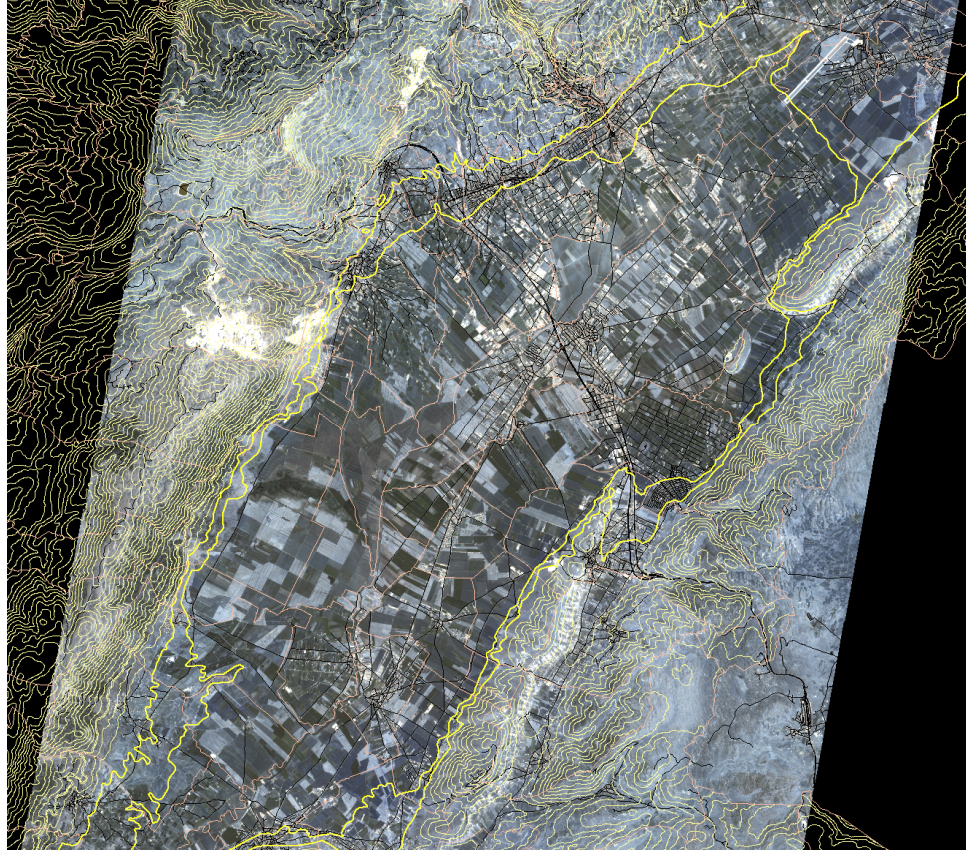


Figure 3.1: Study area with topography lines. Produced with Planetscope 3m imagery using Trimble Ecognition.

### **3.Methods**

#### **3.1 Parametrizing the Classification System**

Using the ground-truthing points collected on the field and the land use classification system from the Lebanon's National Council for Scientific Research Remote Sensing Center in Lebanon (RSCL), the following characteristics were considered the classification system for the built, natural, and cultivated landscapes of the Beqaa Valley.

- **Built Landscapes** in the Beqaa Valley were classified using 5 criteria:
  - Density, determined by number and proximity of buildings. High density reflect built environments with closely spaced buildings whereas low density represent buildings spaced further apart, separated by natural or agricultural landscapes. It is important to note that the highest density in the Beqaa remains lower than its regional urban counterparts (Beirut, and Damascus)
  - Street Grid, determined by the footprint of transportation infrastructure. A highly regular transportation grid represents geometrically consistent road segments, equally spaced, whereas an irregular grid represents geometrically diverse road segments with unequal spacing. Regular grids were most evident in high density fabric on flat surfaces and irregular grids were most evident on older and lower density fabric on slopes.
  - Architectural heterogeneity, determined in the degree of difference in building height and architectural style. Inconsistent styles are observed in older built environments that incrementally developed over time, where older buildings were juxtaposed with newer ones. Morphological consistencies were at their highest in larger developments such as hospital and educational campuses.
  - Land use heterogeneity, determined by the number of uses in a built environment. Other than industrial buildings, educational and health campuses, there were very few lands with singular land use. Low heterogeneity is frequently observed in recently constructed neighborhoods, exemplified in residential apartment buildings with a small shop on the ground floor (small grocery, hair salon, bakery, cell phone shop, etc.) High heterogeneity is evident in built environments close to the main roads and older

built environments where buildings host small shops, offices, residential, governmental, and in some cases religious uses.

- Open space, which falls under 5 categories. ‘Private’ is a yard enclosed in high walls; ‘semi-private’ is a space adjacent to the building separated from the public realm by an elevation change (a few steps higher or lower) or a permeable vertical plane (short wall, wrought iron); ‘flex space’ is space adjacent to the building with no boundary separating it from the public realm; ‘green space’ is space adjacent to buildings that are open to the public.

- **Agricultural landscapes** were distinguished under 4 main classes: crops, orchards and vineyards, and terraces. These classes by function of vegetation morphology (height, structure) and topography (terraces can only be found on slopes, whereas crops are on flat fields). **Infrastructure** classes included infrastructure that have a distinguishable visible footprint that can be identified in the segmentation process. Ancillary datasets were used to inform the classification process. Two classes only were distinguished: Road and Rail. Other forms of infrastructure such as water, sewer, and electric lines were not considered in the classification process. **Industrial environment** include footprints for factories and manufacturing facilities. **Natural Landscapes** and **Water** classes were largely retained from the RSCL datasets. The only exception to that were the quarry landscapes, which were identified by segmentation and spectral signatures.

Expert or site-specific knowledge and ontological considerations in categorizing objects (buildings, trees, surfaces) were integrated with aspects of scale in the construction of the classification system. With a spatial resolution of 3 meters/pixel, the

extraction of an individual object (roof, tree canopy, sidewalk) was not consistently possible. To remedy that, ancillary data were used to extract roads, rail, waterbodies, and natural parks. For the rest of the classes, we use the ‘fabric’ or the ‘landscape’. The classification system in figure 3.2 used to extract these features. This enabled the classification process but also posed a limitation on the level of detail that could be extracted. For example, differentiating types of built environments were possible at level 02, but not at level 3.

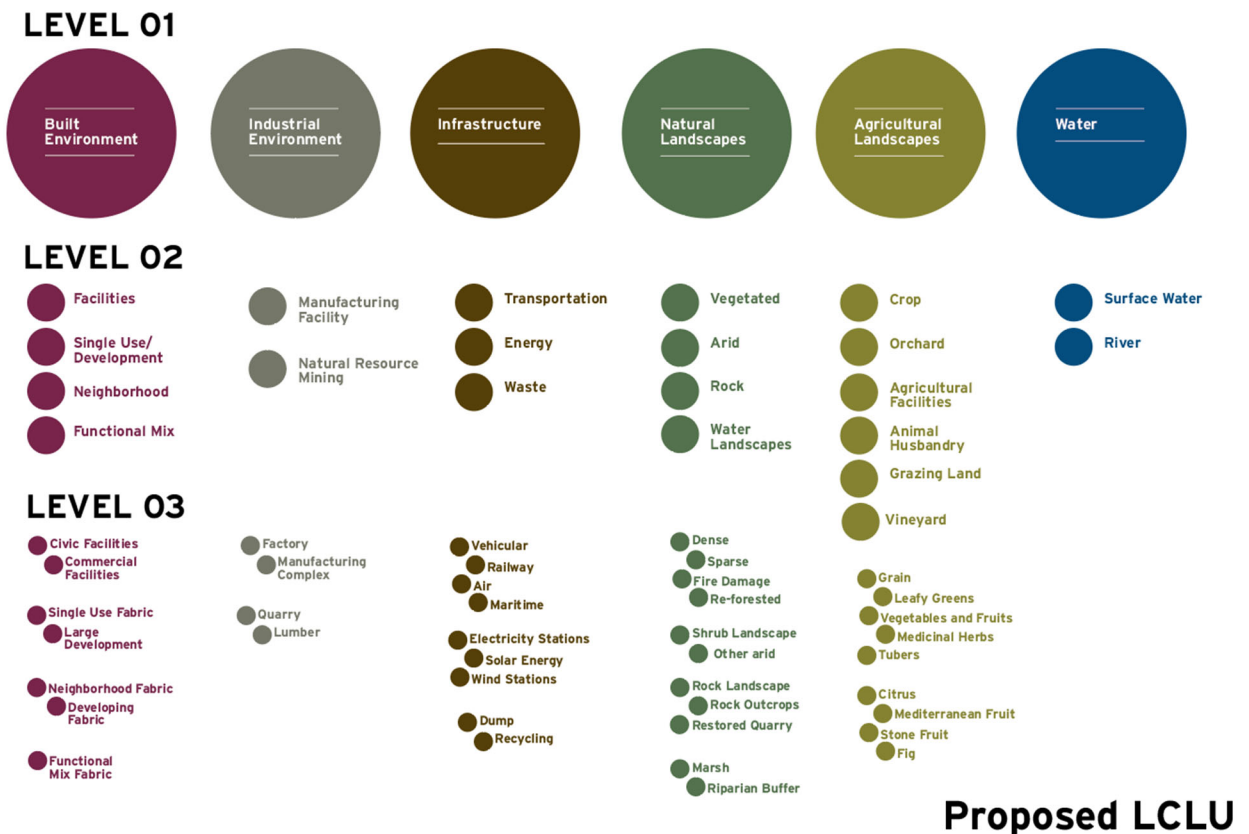


Figure 0.2 Proposed Land Cover Land Use classification system.

## Description of the Classification System for the Beqaa Plains

### Built Environment:

- **Facilities:** refers to large buildings and establishments with distinct footprints such as sports stadia, large hotels, public markets, and malls.
- **Single Use / Developments:** refer to very low density fabrics that are residential or to developed or planned neighborhoods.
- **Neighborhoods:** are the fabrics where single family style detached housing and residential apartment buildings are prominent. This fabric also contains small goods and services shops
- **Functional Mix:** the fabrics that have more commercial and civic uses than the neighborhood but still accommodate residential units, typically found near high traffic areas.

**Industrial Environment:** Primarily food industry, agricultural, steel, ceramic, and paper. Quarry sites are also classified as industrial.

**Agricultural Landscapes:** Crops, vineyards and orchards are all classified as one type of fabric. Smaller orchards and gardens located between houses (seen in single use or neighborhood fabrics) may be distinguished in the classification.

### Natural Landscapes:

- **Arid:** found primarily on the slopes of the Lebanon and Anti-Lebanon mountain ranges.

- **Vegetation:** Tree and shrub cover on the fringes of the built environment and on slopes. Trees within the built environments are not always distinguished due to the scale of the area of study (regional).

- **Parks:** Natural conservations and public Beqaa.

- **Water:** Rivers and retention ponds.



Figure 3.3 Site photos and aerial views of proposed LCLU classes.

Below are the parameters and actions used in the proposed workflow. Definitions and descriptions are extracted from the Ecognition Developer Manual (Trimble Germany GmbH, 2019) and tailored to the processes conducted in this project.

<b>Table 06: Descriptions of parameters and Algorithms</b>		
<b>Parameter</b>	<b>Description</b>	<b>Definition</b>
Area_ex (pxl)	Object area excluding existing inner polygons	Area of objects in pixels, excluding area of enclosed inner objects.
Brightness	Object Brightness	Mean intensity of 4 bands for an object, defined as $\frac{R+G+B+NIR}{4}$
Compactness	Object Compactness	The ratio of the area of a polygon to the area of a circle with the same perimeter, defined as $\frac{4 \times \pi \times area}{perimeter^2}$
Rectangular Fit	Object rectangular fit	Describes how well an image object fits into a rectangle of similar size and proportions. 0 indicates no fit, 1 indicates a complete fit.
GLCMc_PCA3_90	Grey Level Co-Occurrence Matrix Contrast for the PCA3 band considering a horizontal direction.	The gray level co-occurrence matrix (GLCM) is a tabulation of how often different combinations of pixel gray levels occur in a scene. The contrast measures local variation in the band in the horizontal direction.
Rel. border	Relative border to object	Rel. border is the relative border length an object shares with neighbor objects of a certain class. It describes the ratio of the shared border length of an image object (with a neighboring image object assigned to a defined class) to the total border length.

<b>Algorithm</b>	<b>Acronym</b>	<b>Definition</b>
Merge region	Merge	Neighboring objects of the same class and presenting specific characteristics are merged into bigger objects.
Multi-Resolution Segmentation	MRS	Bottom-up segmentation is algorithm that subdivides images or objects into smaller objects at a pixel level to create homogeneous objects. MRS uses 3 homogeneity criterion: color, smoothness, and compaction.
Multi-Threshold Segmentation	MTS	Creates image objects based on user-created thresholds or pixel values thresholds.
Unsupervised classification	US	Iterative Self-Organizing Data Analysis Technique (ISODATA) creates an image layer with 8 or less classes. US image layers are used with MRS or MTS to create objects
Remove Objects	Remove	Removed object will be absorbed into the nearest neighbor or enclosing object.
Majority Vote (Count)	MV_Count	Classifies super-objects based on the class of largest number of sub-objects belonging to a single class.
Majority Vote (Area)	MV_Area	Classifies super-objects based on the class of the largest area of a single class of sub-objects.

## 2.2 Layer Preparation

This paper adopts a Decision Tree (DT) approach to segment and classify the multispectral (3 m) imagery obtained from PlanetScope. With the development of software such as Ecognition and ENVI and the increasing availability of VHR satellite imagery, iteration and comparison has become increasingly affordable, which allows supervised and unsupervised GEOBIA classification processes unique to the area of study and the comparison of accuracy levels. However, declaring the superiority of one

classifier (Random Forest, Nearest Neighbor, Support Vector Machine, Convolutional Neural Networks, Kernel Transformation and others) remains constrained by the characteristics of the area of study and the types of landscape investigated (Ma et al., 2017). The same can be stated for segmentation parameters especially in attempts to classify built environments without a priori knowledge of the relationship between spectral signatures and the real object on the ground (Kohli et al., 2016).

- **Step 1: Dividing into regions.** First, the area of study was dissected into 2 subsets: the plains and slopes. The reason for that is the built environment develops differently as illustrated in section 2.3.1. The focus for this workflow is the segment of the Beirut – Damascus road network in the Beqaa Valley This included most of the Beqaa Caza, and a significant part of the Baalbek-Hermel Caza. The classification process was not conducted on the slopes.

- **Step 2: Preparing Process Image Layers.** Three Principle Component Analysis Layers (PCA) for all spectral layers were created to inform the multi-threshold segmentation process for steps 4 and 5. PCA is a statistical form of data compression that reduces the dimensionality of spectral data and, in turn, facilitates feature extraction (Jensen, 1986a). For imagery analysis, PCA is a productive image enhancement method that compresses spectral bands that show redundancy and repetition, and yields bands of data that are simplified and are more interpretative to the eye (ERDAS Inc., 2005). **Fig.3** shows a subset of the PCA bands for the classification process and how they compare with the other bands. PCA 2 was used to discern areas that are built-up and areas that are not built – up. PCA is considered an enhancement is helpful in informing segmentation, which is the action of subdividing images at or specific image objects from other domains

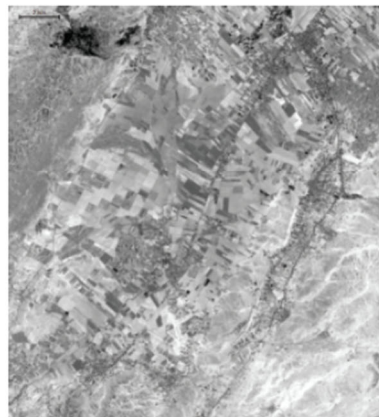
into smaller image objects (Trimble Germany GmbH, 2019). The histogram for the PCA2 was then modified to allow the data to span between the values of 0 and 255. Adjusting the histogram to increase the range value facilitates unsupervised classification and assigning class functions.



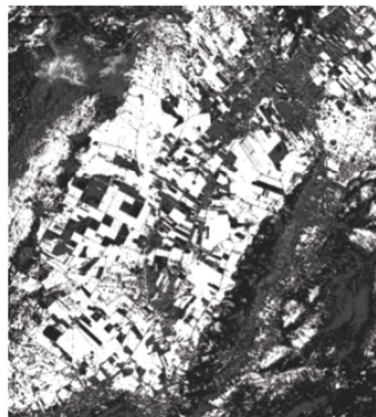
PlanetScope Imagery - true color showing a subset of the study area that contains agricultural fields and small towns surrounded by mountainous ranges.



PCA 2 layer is useful in delineating the extent of the built environment (low values) and identifying agricultural fields (high values).



PCA 3 layer shows texture in the built environment which was useful in distinguishing between historic and high density built environment.



Unsupervised classification using Red band and the PCA 2 layer - the simplified thresholds was useful in identifying isolated roofs in agricultural landscapes.

Figure 0.4. PCA layers used for texture and classification.

## **2.3 Classification**

### **Level 01: Integrating Ancillary data and Separating Built, Agriculture, and Landscape Fabrics.**

Classification using thematic layers: A Multi-Resolution segmentation was conducted using the layers for water, road network, rail line, and the natural conservation areas to create image objects. The rest of the objects were merged under one class “Plains”. The parameters for the multi-resolution segmentation were Parameters: Compactness: 0.5, Shape:0.5, Scale Parameter: 75. Scale parameters in multi-resolution segmentation control the size of the object, where smaller parameters create smaller object and larger parameters create larger objects (Trimble Germany GmbH, 2019). While there is a value in standardizing scale parameter choice in the intent of working with mixed objects in urban settings (Johnson & Jozdani, 2018), the decision for the scale parameter was iterative, with the goal of sequestering roofs or fabrics with similar brightness and texture. Following the segmentation process, objects with low mean PCA 2 values (<180) and high Brightness values (>800) were classified as Built Environment, and objects with a high rectangular fit and high PCA2 – Modified mean values were classified as agricultural. Since the project was tiled to streamline the algorithms, the thresholds for the PCA 2 and Brightness values were adjusted slightly depending on the tile the ranges for the PCA 2 values for this step ranged between 160 and 180, and ranges for high Brightness ranged between 800 and 1000.

**Level 02: Segmenting the Built Environment.**

On Image Object Level 02, objects belonging to the “Built Environment” class with areas under 500 pixels and with high rectangular fit ( $>0.7$ ) were classified as “Built Roof”. This was necessary to remove the number of objects from consideration for the next step and in turn make the thresholds manageable: roofs tended to have very low GLCM levels due to their smaller area and different brightness values (due to the various material used in buildings such as brick, tar, asphalt, concrete, etc.). The “Built Environment” Class was merged, and another MRS was conducted using the PCA 2 , PCA 3 , and Red bands, and a scale parameter is 50. This was done to cluster objects with similar PCA 2 and 3 values which facilitates identifying GLCM thresholds and reduces mis-classification. The values Brightness and GLCMc\_PCA3\_90 values for the remaining objects belonging to the “Built Environment” class were then examined. Using a matrix, class assignments were assigned based on the values.

<b>Table 07: Process classes divided by brightness and GLCM matrix.</b>				
		<b>Brightness</b>		
		Low <1000	Medium 1000 - 1300	High >1300
<b>GLCMc_PCA3_90</b>	Low <500	Agricultural Field	Low Density	Low Density
	Medium 500 - 100	Dark Built Fabric	Light Built Fabric	Bright Built Fabric
	High >1000	Dark Built Fabric	Light Built Fabric	Bright Built Fabric

Agricultural fields on average have little texture and low brightness. Upon inspection of the “Built\_Environment” objects, there were agricultural objects that were classified as built environment, and they possessed low values on both. Low density fabric demonstrated higher mean brightness, where a few bright buildings were dispersed on an agricultural plot, which explains why the contrast was minimal. The dark built fabric corresponds to newer buildings and/or shorter buildings so the contrast was higher seeing how buildings were evenly but closely spaced. The light built fabric corresponds to primarily small buildings in older towns and neighborhoods. Older quarters typically are a mix of bright and brick roofs and are very closely knit. Bright built fabric signifies very reflective surfaces, which are primarily industrial buildings and refugee settlements in addition to tall buildings. Classifying objects based on these thresholds will help distinguish between different urban fabrics that would then inform the final classification.

Some urban objects, typically very small roofs surrounded by fields, were classified as agriculture. To remedy that, a contrast split segmentation on agricultural field is conducted using the PCA 2 and Red Unsupervised classification layer. This separated bright and dark objects. Bright object with an area of <500 pixels were classified as “Built\_Roof”, and the rest were reclassified as Agriculture.

This step is essential for the classification because towns and neighborhoods in the Beqaa in their nature have very different types of buildings that are closely juxtaposed that in turn compete to dictate the aspect of the town. For example, some older towns have some stretches of more modern built fabric. That doesn’t necessarily mean that the town is entirely historic, and it does not mean that the town is modern. There is no clear

way to classify the fabric without discerning which stretches are more historic and which are more modern.

### **Level 02: Classifying the Built Environment.**

An image object level “Level 02 – Classify” was created above Level 02, thus holding the classes Agriculture, Built Environment, Transportation, Natural, Water. Built Environment was then classified using the Majority vote area feature. Objects with a majority area of “Dark built fabric” were classified as “Functional Mix”, those with a majority of “Light built fabric” were classified as “Neighborhood”, and those with a majority of “Bright Built Fabric” were classified as “Industrial”. Fabrics with a majority of “Low\_Density” or “Built\_Roof” with a relative border to agriculture greater than 0.7 were classified as “Single Use Fabric”.

Landscape Areas misclassified as bright roofs were manually reclassified as “Landscape Rock” or “Landscape Arid”. This was visible on some slopes and since the area of study excluded the mountainous ranges, the workflow did not include segmentation of classification processes to distinguish between build and vegetative landscapes of slopes.

### **2.4 Validation**

**Photo** interpretation was intermittently used for accuracy assessment and adjusting workflow by checking the classification results with the ground truthing data points collected on site. An accuracy table was created by assessing whether the classification matches the data point(Kohli et al., 2016; Salehi et al., 2012).

The process for final validation included importing the classification results into ArcGIS pro as polygon layers, performing a spatial join of the ground truthing points to the results layers. The attribute table was then exported to excel and using simple text formulas, we were able to compare between the assigned class of the ground truthing data point and the classified result of the classification workflow proposed in this paper.

#### **4. Results**

For the Level 01 classification accuracy levels were at 72.19%, which means the algorithm was mostly successful in discerning built from non-built environments. The deployment of thematic layers, especially roads, was conducive to extracting the boundary of the built environment and portraying the organization of cities and towns in the Beqaa. The rivers thematic map was helpful in identifying natural landscapes. In comparison Kohli et al.'s attempt to classify slum versus non-slum was at 60% with fewer classes. This current accuracy level is far from ideal, but it is very promising. Level 02 classification accuracy levels were at 57.69%, which could be improved in part by raising the accuracy levels of Level 01, and by distinguishing classes where most confusion takes place, such as quarry sites/industrial environments, and functional mix/neighborhood.

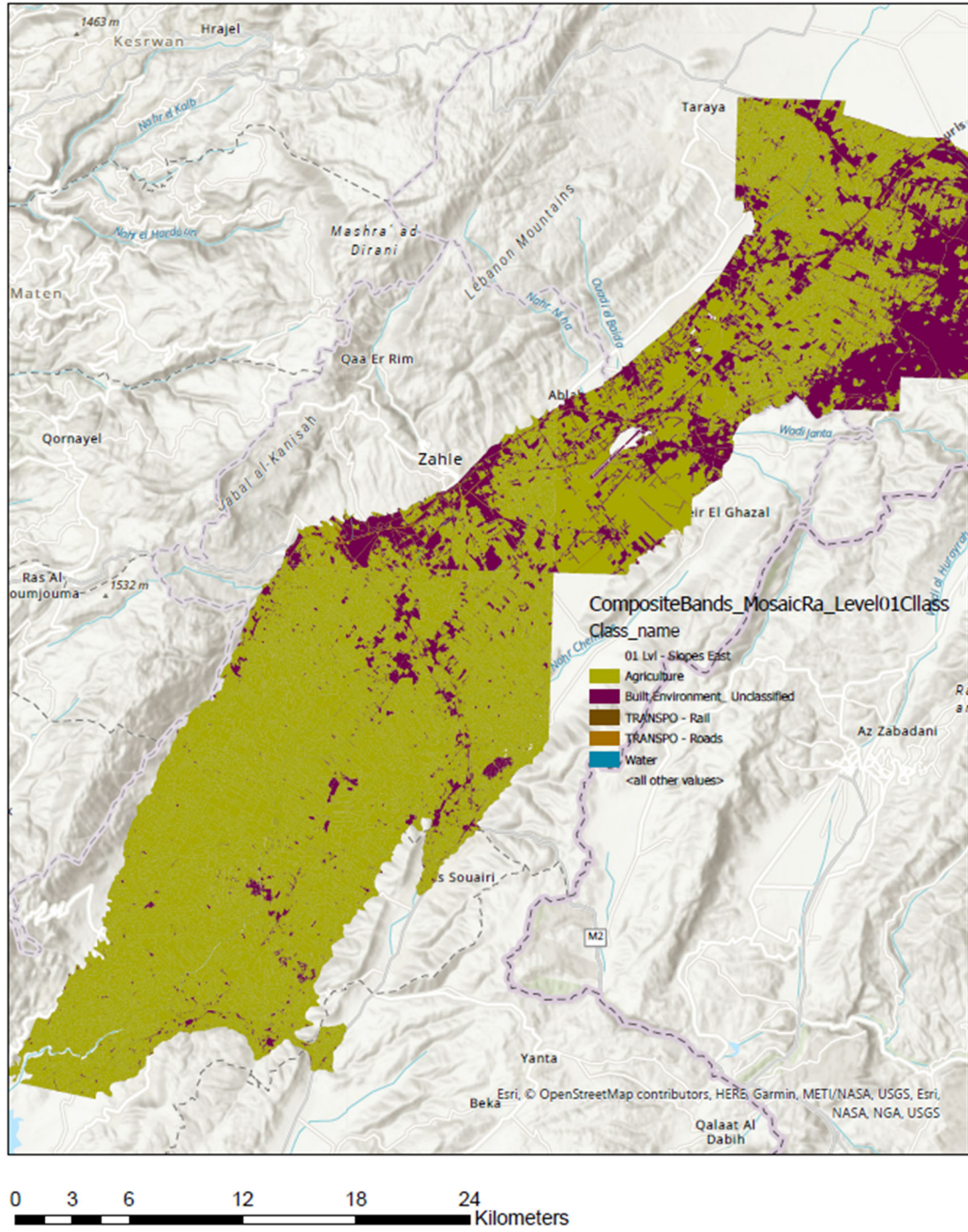


Figure 0.5. Classification Results for Level 01

Other prevalent misclassifications occurred between industrial and refugee settlements, due to similarity in GLCM values. Some polygons that are Functional Mix with a low reflectance value (painted with asphalt or simply concrete) with a high rectangular value were also misclassified as agricultural, which would explain the accuracy at Level 01.

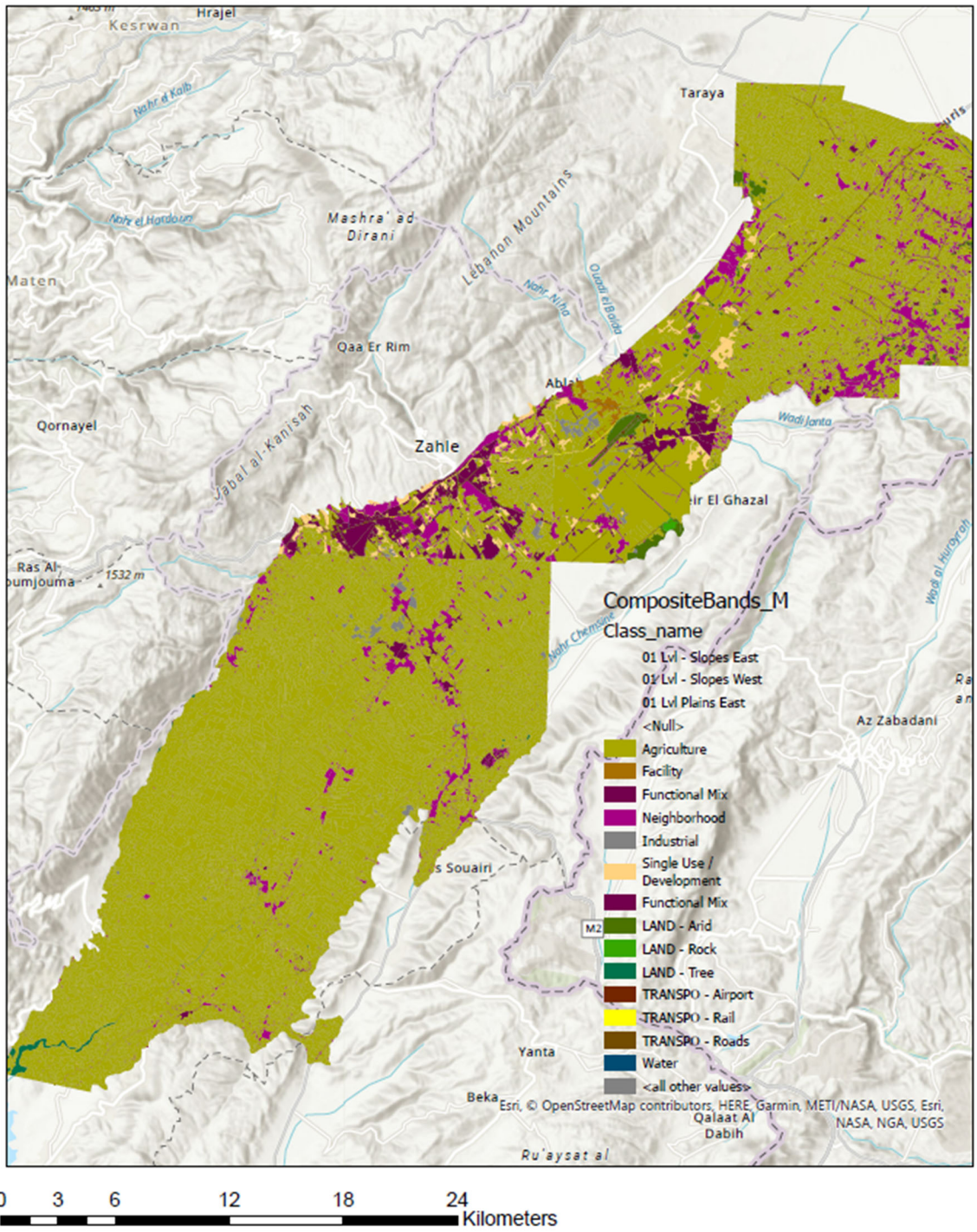


Figure 0.6 Classification results for Level 02 (built environment). Level 01 is depicted with the same detail.

Furthermore, the classification process was conducted by tile, which led to some discrepancies in the classification. This can be remedied by merging the layers prior to classification and adjusting the mean RGB values to the most productive values.

Another approach to gain more accuracy would be to do the opposite – reduce the surface area analyzed, which increases the chances of finding imagery tiles that cover the area and in turn raise the accuracy level.

## **5. Discussion and Conclusions**

### **5.1 Advantages**

Advantages of this semi-automated classification process stem from its attention to the area's specific spectral, brightness, and textural properties and its relatively low computational cost, and the ability of the workflow to accommodate expert input provides an opportunity to de-silo different spatial data to create case-specific classification. Further, it allows for citizen input especially from non-profit and local planning actors such as Public Works Studio (2020, *باستديو أشغال عامة*), who have worked on identifying quarry locations using point data. These point data can become thematic layers just like infrastructure and water layers to classify known entities at the earliest stage of the classification process. Other sources of citizen data include the Litani River Authority's work on cleaning up the river banks and dismantling construction that veers into the riparian buffer. Tracking their work using GPS trackers would similarly result in a thematic layer that would be updated regularly to document the progress and the total area restored. Should Open Street Maps benefit from input from local citizens, the

resulting polygon layer can enrich the classification of facilities, which are near impossible to correctly classify at levels 03 and 04 without input.

The process' speed and affordability can generate updated LCLU maps more frequently, and its interoperability (exporting polygon shapefiles) enables it to post results on ArGIS online or other online platforms.

## **5.2 Applications, Limitations, and Future Research**

Applications to planning and land stewardship Compared to existing LULC class generated by Remote sensing center in Lebanon, this reveals more information on the landscapes and creates a representation that goes beyond centers and conurbations (Verdeil et al., 2012c). Planning on a municipal level can benefit from this map to understand the rough land cover and the degree of overlap between jurisdictions and identifying potential sustainable development options. An example is planning for public transit routes along the Beirut-Damascus road.

Thematic vector layers were incomplete which led to missed representations. This is not hard to overcome with a collective effort in digitizing roads and identifying landmarks in the Beqaa valley through Open Street Maps. Furthermore, road typologies can be used to help discern between historic fabric from modern fabric. The road layer used in this research did have some typology in the attribute table, but the classification of these typologies was not consistent and was thus not used. To increase the classification accuracy, different pattern indices can be used depending on the main direction of the road but the manner of determining the direction and layer need specific systemization processes to avoid drastically increasing the computational cost of this workflow. Alternatively, higher resolution

imagery (<1m) can help discern roof sizes and materials and in turn single out landmarks with unique roof sizes and spectral signatures such as mosques (typically having domes) , markets (large concrete surfaces with temporary covers). Specifically to the process, at the classification of landscapes based on their GLCM and their Brightness values, the natural breaks were identified based on iteration. But it is possible to be more methodical, using Jenks or K-means clustering. This process also requires staying abreast the developments in data availability and shifting the workflow to match new spectral and resolution data. Between the beginning of this study and today, planetscope published a new imagery set which boasts eight spectral bands, which would provide more opportunities for higher accuracy. It is important to note that while the classification workflow would change, the classification set is not dictated by technological changes. On the contrary, it is shaped by data collected on the field and how this spatial data is visible in remote sensing data. For example, if more apartment buildings in the Beqaa began investing in green roofs, this change would be observed on the field and assessment to the overall function of the building in the built environment is assessed there too. Seeing how the spectral signature of buildings would change, a modification to the workflow would be needed.

Comparisons between the ESRI global landcover and the LCLU map and the proposed workflow demonstrates that the number of classes are similar but more descriptive of the area, which improves the legibility of the map. The geometric profile of the land uses conforms to the land covers and land uses to a greater degree. Overall, it is a functional process with capability of becoming more accurate and update at a speedier rate, providing for more spatial data for planning purposes.



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## CONCLUSIONS

There is definite need to rethink how Lebanon cartographically represents the Beqaa as part of the country. The urban fabric in the Beqaa demonstrates intricacies that go beyond the agricultural and the natural realms. With the current technology, it is feasible to embark on alternative methods of mapping and to include counter-mapping and citizen science. Lebanon's census was not documented since 1932, and in that dataset, the Beqaa district has the largest surface, yet is the least dense. In the watershed of the 2019 revolution against the continuously failing state, recent efforts emerged to create an updated census. This may reflect that the Beqaa's population have now become a critical mass in need of more attention to the urban condition of their cities and towns. While the reach of Lebanon's national planning efforts may be limited in the Beqaa, local governance such as municipalities and the litany river authority, along with other stakeholders concerned with sustainable development can use more detailed spatial information to gauge methods of engagement and prioritize areas critical to comprehensive and equitable planning. In that sense, an updated mapping methodology, rapid and comprehensive, is necessary.

With the current technological advancements in open mapping, community-based knowledge and citizen science, integrating input from the denizens and local institutions of the multiple areas can generate a more comprehensive representation of the built environment beyond the existing binaries (planned and unplanned, central and sprawl) to

categories, or even a spectrum, that reflect how the built environment functions, to what needs it responds, and how well it serves its denizens. Non-profit and academic entities are leading the way for more pluralistic approaches to mapping such as Public Works Studio (Public Works Studio Projects, 2020) documenting issues such as environmental dangers of stone quarries owned by the political ruling class (2020, *استديو أشغال عامة*) and the right to equitable housing by harvesting narratives from the residents of the studies towns, villages, and neighborhoods and activating public input via launching of competitions or public forums (2020, *استديو أشغال عامة*) that are less concerned with standardization of a corpus of spatial information according to fit the traditional part of an atlas.

Other examples that leverage the art and science of cartography today include critical mapping at the Beirut Urban Lab, a research lab at the American University of Beirut investigating issues that speak to the very ontological question of how Lebanon is mapped. A very relevant example of that is rethinking the boundaries of Beirut neighborhoods and considering the new role of map production in an age of data availability (Gharbieh, 2015) and also migrating some of the atlas components from static layers towards living atlases and online databases (Beirut Urban Lab, 2020). Another example is Visualizing Palestine, a group of researchers, designers, and technologists utilizing data to advance a factual, rights-based narrative of the Palestinian-Israeli issue. Their platform, Palestine Open Maps (Palestine, 2018), shows the historic changes in Palestine, shedding light on the displacement, violence, and reconstruction of the built environment. For all three examples mentioned, it is important to note that visual design is a critical element to their success, which is to say abundance of availability in data

does not necessarily mean that atlases or maps are obsolete. Quite the contrary: cartography is, if anything, more needed to manage spatial quantitative and qualitative data to produce visuals that are legible and functional.

The proposed hybrid mapping workflow in this research starts with an urban morphological approach in investigating the distinct typologies of the Beqaa and concludes with the implementation of the field knowledge into a classification workflow.

The proposed workflow in this research is not restricted to the Beqaa. It focuses on deconstructing and understanding the commonplace architecture of the urban environment, which is the outcome of human actions and behaviors (Carter & Collins Cromley, 2005) in their aspiration to navigate the constraints placed upon them by their economic, social and environmental circumstances while also aspiring towards modernity (N AlSayyad, 2014). In that sense, it is transferable to any peri-urban and rural town not only in areas deprived of geospatial knowledge but also in areas where data is abundant. The information generated by this workflow are not necessarily represented in zoning and future land use maps because they inherently represent the as-built, the lived space as it is used by the community.

The spatial knowledge related to urban planning that this approach can yield is a more comprehensive portrayal of the built environment condition in the Beqaa valley outside the labels of ‘haphazard’ or ‘illegal’ which seem to cause gridlock due to the government’s inability to consistently govern and regulate. To provide an example: if there was an intention to create a continuous multi-modal transportation corridor

connecting the towns of central and west Beqaa, this classification can identify the concentrations of high density neighborhoods (Neighborhood – Urban, Neighborhood – Town) to inform the alignment of rail stations and planning for transit routes to fulfill the first and last mile. Fabrics that present abundant surfaces of flex space can be considered suitable building bike and pedestrian routes connecting neighborhood fabrics to functional nodes and rail stations. Another example is should Beqaa'I authorities aim to identify critical areas for historic preservation efforts, this classification system can help identify fabrics with the highest levels of architectural heterogeneity and precise locations of heritage sites for a comprehensive plan.

Advantages of this semi-automated classification process stem from its attention to the area's specific spectral, brightness, and textural properties and its relatively low computational cost, and the ability of the workflow to accommodate expert input provides an opportunity to de-silo different spatial data to create case-specific classification. Further, it allows for citizen input especially from non-profit and local planning actors such as Public Works Studio (2020, *بالاستديو أشغال عامة*), who have worked on identifying quarry locations using point data. These point data can become thematic layers just like infrastructure and water layers to classify known entities at the earliest stage of the classification process. Other sources of citizen data include the Litani River Authority's work on cleaning up the river banks and dismantling construction that veers into the riparian buffer. Tracking their work using GPS trackers would similarly result in a thematic layer that would be updated regularly to document the progress and the total area restored. Should Open Street Maps benefit from input from local citizens, the resulting polygon layer can enrich the classification of facilities, which are near

impossible to correctly classify at levels 03 and 04 without input. Comparisons between the ESRI global landcover and the LCLU map and the proposed workflow demonstrates that the number of classes are similar but more descriptive of the area, which improves the legibility of the map. The geometric profile of the land uses conforms to the land covers and land uses to a greater degree. Overall, the proposed workflow, when needed is a functional process with capability of becoming more accurate and update at a speedier rate, providing for more spatial data for urban and environmental planning purposes.

Limitations of this study stem from the sample size used to classify the fabrics of the Beqaa. Undoubtedly, more samples from towns in South Beqaa and further north would eliminate any imminent redundancies. Comparisons with land classes on coastal cities would also make for a more functional classification system to be used in Lebanon. Deeper knowledge of the architectural history in the Beqaa valley would also be helpful in understanding the inner mechanics of the built environment, specifically the juxtapositions of traditional and modern styles of building as well as information about dwellers and economic status. Thematic vector layers were incomplete which led to missed representations. This is not hard to overcome with a collective effort in digitizing roads and identifying landmarks in the Beqaa valley through Open Street Maps. Furthermore, road typologies can be used to help discern between historic fabric from modern fabric. The road layer used in this research did have some typology in the attribute table, but the classification of these typologies was not consistent and was thus not used. To increase the classification accuracy, different pattern indices can be used depending on the main direction of the road but the manner of determining the direction

and layer need specific systemization processes to avoid drastically increasing the computational cost of this workflow. Alternatively, higher resolution imagery (<1m) can help discern roof sizes and materials and in turn single out landmarks with unique roof sizes and spectral signatures such as mosques (typically having domes) , markets (large concrete surfaces with temporary covers).

Specifically to the process, at the classification of landscapes based on their GLCM and their Brightness values, the natural breaks were identified based on iteration. But it is possible to be more methodical, using Jenks or K-means clustering. This process also requires staying abreast the developments in data availability and shifting the workflow to match new spectral and resolution data. Between the beginning of this study and very recently, PlanetScope published a new imagery set which boasts eight spectral bands (Planet News, 2022), which would provide more opportunities for higher accuracy. It is important to note that while the classification workflow would change, the classification set is not dictated by technological changes. On the contrary, it is shaped by data collected on the field and how this spatial data is visible in remote sensing data. For example, if more apartment buildings in the Beqaa began investing in green roofs, this change would be observed on the field and assessment to the overall function of the building in the built environment is assessed there too. Seeing how the spectral signature of buildings would change, a modification to the workflow would be needed.

### Appendix A: Validation Table for Article 03: Class 01

site name	Ground Truthing Level 01	Classified Level 01	Validate
Entrance from roundabout to bar elias	Built Environment	Agriculture	Inaccurate
Bar Elias entrance from roundabout	Built Environment	Agriculture	Inaccurate
Bar elias deir znoun corridor 1	Built Environment	Agriculture	Inaccurate
Bar elias deir znoun corridor 2	Built Environment	Agriculture	Inaccurate
Bar elias chafic jamil supermarket	Built Environment	Agriculture	Inaccurate
Bar elias side rd	Natural Landscape	Agriculture	Inaccurate
PAC Taanayel corridor	Built Environment	Agriculture	Inaccurate
Chtaura inner agri field	Agriculture	Agriculture	Accurate
Chtaura inner agri	Agriculture	Agriculture	Accurate
Anjar Main road	Natural Landscape	Agriculture	Inaccurate
Water canal	Natural Landscape	Agriculture	Inaccurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Mosque ozeir	Built Environment	Agriculture	Inaccurate
Agri infoset	Agriculture	Agriculture	Accurate
Camping ground	Natural Landscape	Agriculture	Inaccurate
Public school	Built Environment	Agriculture	Inaccurate
Residential neighborhood	Built Environment	Agriculture	Inaccurate
Domaine de Chouchane	Natural Landscape	Agriculture	Inaccurate
Vacant lot	Agriculture	Agriculture	Accurate
Arcada neighborhood	Built Environment	Agriculture	Inaccurate
Recently shrubbed	Natural Landscape	Agriculture	Inaccurate
Jeb Jannine waterway	Built Environment	Agriculture	Inaccurate
Jeb Jannine Node	Built Environment	Agriculture	Inaccurate
Small Villas kamed	Built Environment	Agriculture	Inaccurate
Agri wheat	Agriculture	Agriculture	Accurate
Pharmacy jhar commercial	Built Environment	Agriculture	Inaccurate
Infoset established, also historic urban	Built Environment	Agriculture	Inaccurate
Agri cabbage	Agriculture	Agriculture	Accurate
Pipe factory	Agriculture	Agriculture	Accurate
Cow hangar	Agriculture	Agriculture	Accurate

Villas on agri	Built Environment	Agriculture	Inaccurate
Nursery	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Ghazze park	Natural Landscape	Agriculture	Inaccurate
معمل السكر	Industrial	Agriculture	Inaccurate
Agri natour house	Agriculture	Agriculture	Accurate
Public train park	Natural Landscape	Agriculture	Inaccurate
Church on Agri field	Agriculture	Agriculture	Accurate
Water pump and collection lake	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Mashrou3 farz	Natural Landscape	Agriculture	Inaccurate
Officer apt housing	Agriculture	Agriculture	Accurate
Amaleen	Water	Agriculture	Inaccurate
Mandara village	Natural Landscape	Agriculture	Inaccurate
Farm	Agriculture	Agriculture	Accurate
Industrial	Industrial	Agriculture	Inaccurate
Agri land and construction	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri misc	Agriculture	Agriculture	Accurate
Ammiq Swamplands	Natural Landscape	Agriculture	Inaccurate
Sett sha3wane mazar	Natural Landscape	Agriculture	Inaccurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri terraces	Agriculture	Agriculture	Accurate
Sicomo	Natural Landscape	Agriculture	Inaccurate
Agri potato	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Serail jeb jannine neighborhood	Built Environment	Agriculture	Inaccurate
Agri nursery	Agriculture	Agriculture	Accurate
Agri nursery	Natural Landscape	Agriculture	Inaccurate
Qab Elias veggie market	Built Environment	Agriculture	Inaccurate
Mekseh mix road	Built Environment	Agriculture	Inaccurate
Public parklet	Agriculture	Agriculture	Accurate
Villa quarter	Natural Landscape	Agriculture	Inaccurate
public petting zoo	Agriculture	Agriculture	Accurate
Horse barn	Agriculture	Agriculture	Accurate

Khiara entrance	Agriculture	Agriculture	Accurate
Agri land	Agriculture	Agriculture	Accurate
Agricultural terraces	Water	Agriculture	Inaccurate
Retention pond	Water	Agriculture	Inaccurate
Pond	Water	Agriculture	Inaccurate
Data point 1	Agriculture	Agriculture	Accurate
Data point 2	Agriculture	Agriculture	Accurate
Data point 3	Agriculture	Agriculture	Accurate
Data point 4	Agriculture	Agriculture	Accurate
Data point 5	Agriculture	Agriculture	Accurate
Data point 6	Agriculture	Agriculture	Accurate
Data point 7	Agriculture	Agriculture	Accurate
Data point 8	Agriculture	Agriculture	Accurate
Data point 9	Agriculture	Agriculture	Accurate
Data point 10	Agriculture	Agriculture	Accurate
Data point 11	Agriculture	Agriculture	Accurate
Data point 12	Agriculture	Agriculture	Accurate
Data point 13	Agriculture	Agriculture	Accurate
Data point 14	Agriculture	Agriculture	Accurate
Data point 15	Agriculture	Agriculture	Accurate
Data point 16	Agriculture	Agriculture	Accurate
Data point 17	Agriculture	Agriculture	Accurate
Data point 18	Agriculture	Agriculture	Accurate
Data point 19	Agriculture	Agriculture	Accurate
Data point 20	Agriculture	Agriculture	Accurate
Data point 21	Agriculture	Agriculture	Accurate
Data point 22	Agriculture	Agriculture	Accurate
Data point 23	Agriculture	Agriculture	Accurate
Data point 24	Agriculture	Agriculture	Accurate
Data point 25	Agriculture	Agriculture	Accurate
Data point 26	Agriculture	Agriculture	Accurate
Data point 27	Agriculture	Agriculture	Accurate
Data point 28	Agriculture	Agriculture	Accurate
Data point 29	Agriculture	Agriculture	Accurate
Data point 30	Agriculture	Agriculture	Accurate
Data point 31	Agriculture	Agriculture	Accurate
Data point 32	Agriculture	Agriculture	Accurate
Data point 33	Agriculture	Agriculture	Accurate
Data point 34	Agriculture	Agriculture	Accurate
Data point 35	Agriculture	Agriculture	Accurate
Data point 36	Agriculture	Agriculture	Accurate
Data point 37	Agriculture	Agriculture	Accurate
Data point 38	Agriculture	Agriculture	Accurate

Data point 39	Agriculture	Agriculture	Accurate
Data point 40	Agriculture	Agriculture	Accurate
Data point 41	Agriculture	Agriculture	Accurate
Data point 42	Agriculture	Agriculture	Accurate
Data point 43	Agriculture	Agriculture	Accurate
Data point 44	Agriculture	Agriculture	Accurate
Data point 45	Agriculture	Agriculture	Accurate
Data point 46	Agriculture	Agriculture	Accurate
Data point 47	Agriculture	Agriculture	Accurate
Data point 48	Agriculture	Agriculture	Accurate
Data point 49	Agriculture	Agriculture	Accurate
Data point 50	Agriculture	Agriculture	Accurate
Data point 51	Agriculture	Agriculture	Accurate
Data point 52	Agriculture	Agriculture	Accurate
Data point 53	Agriculture	Agriculture	Accurate
Aana	Built Environment	Agriculture	Inaccurate
Natural data 01	Natural Landscape	Agriculture	Inaccurate
Data point 53	Agriculture	Agriculture	Accurate
Data point 54	Agriculture	Agriculture	Accurate
Data point 55	Agriculture	Agriculture	Accurate
Data point 56	Agriculture	Agriculture	Accurate
Data point 57	Agriculture	Agriculture	Accurate
Data point 58	Agriculture	Agriculture	Accurate
Data point 59	Agriculture	Agriculture	Accurate
Data point 60	Agriculture	Agriculture	Accurate
Data point 61	Agriculture	Agriculture	Accurate
Data point 62	Agriculture	Agriculture	Accurate
Data point 63	Agriculture	Agriculture	Accurate
Data point 64	Agriculture	Agriculture	Accurate
Data point 65	Agriculture	Agriculture	Accurate
Data point 66	Agriculture	Agriculture	Accurate
Data point 67	Agriculture	Agriculture	Accurate
Data point 68	Agriculture	Agriculture	Accurate
Data point 69	Agriculture	Agriculture	Accurate
Data point 70	Agriculture	Agriculture	Accurate
Data point 71	Agriculture	Agriculture	Accurate
Data point 72	Agriculture	Agriculture	Accurate
Data point 73	Agriculture	Agriculture	Accurate
Data point 74	Agriculture	Agriculture	Accurate
Data point 75	Agriculture	Agriculture	Accurate
Data point 76	Agriculture	Agriculture	Accurate
Data point 77	Industrial	Agriculture	Inaccurate
Data point 78	Water	Agriculture	Inaccurate

Data point 79	Industrial	Agriculture	Inaccurate
Lebanese American University Campus	Built Environment	Agriculture	Inaccurate
Lebanese American University Campus	Built Environment	Agriculture	Inaccurate
Ksara vinyard peripheries	Agriculture	Agriculture	Accurate
Ksara vinyard peripheries	Agriculture	Agriculture	Accurate
Fancy Church	Built Environment	Agriculture	Inaccurate
Marj	Built Environment	Agriculture	Inaccurate
Haouch Harimeh	Built Environment	Agriculture	Inaccurate
Haouch Harimeh	Built Environment	Agriculture	Inaccurate
Multistory Kamed el Lawz	Built Environment	Agriculture	Inaccurate
Cobra Tech	Built Environment	Built Environment	Accurate
PAC taanayel	Built Environment	Built Environment	Accurate
PAC taanayel corridor waked electric	Built Environment	Built Environment	Accurate
Pac taanayel corridor .1	Natural Landscape	Built Environment	Inaccurate
Pac taanayel corridor .2	Industrial Environment	Built Environment	Inaccurate
Pac taanayel	Industrial Environment	Built Environment	Inaccurate
Bar elias inner neighborhood .1	Built Environment	Built Environment	Accurate
Bar elias inner neighborhood .2	Built Environment	Built Environment	Accurate
Bar elias inner neighborhood .3	Built Environment	Built Environment	Accurate
Bar elias plaza	Built Environment	Built Environment	Accurate
Chtaura villas	Built Environment	Built Environment	Accurate
Qab Elias Neighborhood	Built Environment	Built Environment	Accurate
Zahle Hw .1	Built Environment	Built Environment	Accurate
Zahle Hw .2	Natural Landscape	Built Environment	Inaccurate
Refugee camp	Built Environment	Built Environment	Accurate
Pop up coffee shop	Built Environment	Built Environment	Accurate
Mixed complex	Built Environment	Built Environment	Accurate
Anjar Main road.2	Infrastructure	Built Environment	Inaccurate
Residential neighborhood .2	Built Environment	Built Environment	Accurate
Residential neighborhood .1	Natural Landscape	Built Environment	Inaccurate

Residential neighborhood 2	Natural Landscape	Built Environment	Inaccurate
Recycling bin	Natural Landscape	Built Environment	Inaccurate
Mixed strip	Built Environment	Built Environment	Accurate
Gaidzag and Dzovig stadium	Built Environment	Built Environment	Accurate
Entrance commercial	Natural Landscape	Built Environment	Inaccurate
Ceramic store	Built Environment	Built Environment	Accurate
Mixed use			
Neighborhood WBQ	Built Environment	Built Environment	Accurate
Mosque	Built Environment	Built Environment	Accurate
Mix neighborhood	Built Environment	Built Environment	Accurate
Mix neighborhood	Built Environment	Built Environment	Accurate
Agri land infoset	Industrial Environment	Built Environment	Inaccurate
Residential	Built Environment	Built Environment	Accurate
Neighborhood	Built Environment	Built Environment	Accurate
Residential neighborhood	Built Environment	Built Environment	Accurate
Masnaa limit	Built Environment	Built Environment	Accurate
Commercial	Built Environment	Built Environment	Accurate
Mix neighborhood	Built Environment	Built Environment	Accurate
Heritage	Built Environment	Built Environment	Accurate
Anjar hwy commercial	Built Environment	Built Environment	Accurate
Highway	Natural Landscape	Built Environment	Inaccurate
Centre Khaled mix	Built Environment	Built Environment	Accurate
Parking lot	Built Environment	Built Environment	Accurate
Residential neighborhood	Built Environment	Built Environment	Accurate
Parking lot	Built Environment	Built Environment	Accurate
Commercial neighborhood	Built Environment	Built Environment	Accurate
Doctor's offices	Built Environment	Built Environment	Accurate
Qab Elias Islamic school	Built Environment	Built Environment	Accurate
Mix commercial mn rd	Built Environment	Built Environment	Accurate
Popcorn factory	Built Environment	Built Environment	Accurate
Mix Neighborhood	Built Environment	Built Environment	Accurate
Mix neighborhood hwy	Built Environment	Built Environment	Accurate
Mix style residential neighborhood	Built Environment	Built Environment	Accurate
Notre Dame des Apotres	Built Environment	Built Environment	Accurate
Gas station	Built Environment	Built Environment	Accurate

Commercial residential neighborhood	Built Environment	Built Environment	Accurate
Chtaura damas road neighborhood	Built Environment	Built Environment	Accurate
Al shams commercial mix	Built Environment	Built Environment	Accurate
Stargate	Built Environment	Built Environment	Accurate
Carré rouge mall	Built Environment	Built Environment	Accurate
Residential various	Built Environment	Built Environment	Accurate
Public park	Natural Landscape	Built Environment	Inaccurate
Commercial residential strip on frontage road	Built Environment	Built Environment	Accurate
Residential kamed villa neighborhood	Built Environment	Built Environment	Accurate
Mosque	Built Environment	Built Environment	Accurate
Residential Jeb Jannine slope	Built Environment	Built Environment	Accurate
Construction commercial strip	Built Environment	Built Environment	Accurate
Tile quarry sales	Industrial	Built Environment	Inaccurate
Najah Steel	Industrial	Built Environment	Inaccurate
Gas station	Built Environment	Built Environment	Accurate
Residential under construction	Natural Landscape	Built Environment	Inaccurate
Mill	Industrial	Built Environment	Inaccurate
Granite reseller	Industrial	Built Environment	Inaccurate
Ghazze inner road	Built Environment	Built Environment	Accurate
Public plaza	Built Environment	Built Environment	Accurate
Agri wheat	Built Environment	Built Environment	Accurate
Old rail riyyak	Infrastructure	Built Environment	Inaccurate
Hopital riyyak	Built Environment	Built Environment	Accurate
Sayed farm	Industrial	Built Environment	Inaccurate
Az manufacturing	Industrial	Built Environment	Inaccurate
Aryaf for food processing	Built Environment	Built Environment	Accurate
Junkyard	Industrial	Built Environment	Inaccurate
Soccer field	Built Environment	Built Environment	Accurate
Infoset	Built Environment	Built Environment	Accurate
Najjar and kassatly	Industrial	Built Environment	Inaccurate
Gececo	Industrial	Built Environment	Inaccurate
Taalabaya main strip	Built Environment	Built Environment	Accurate
Taalabaya main commercial	Built Environment	Built Environment	Accurate

Commercial strip taalabaya	Built Environment	Built Environment	Accurate
Beauty women Hawana	Built Environment	Built Environment	Accurate
Vacant lot	Natural Landscape	Built Environment	Inaccurate
Ndj school	Built Environment	Built Environment	Accurate
Taalabaya school campus	Built Environment	Built Environment	Accurate
Church	Built Environment	Built Environment	Accurate
Taanayel commercial corridor	Built Environment	Built Environment	Accurate
Jalala main road neighborhood	Built Environment	Built Environment	Accurate
Chtaura plaza	Built Environment	Built Environment	Accurate
مركز بر اليااس الصحي	Built Environment	Built Environment	Accurate
Bar elias hospital	Built Environment	Built Environment	Accurate
Agri wheat	Agriculture	Built Environment	Inaccurate
Service corridor	Built Environment	Built Environment	Accurate
Taalabaya dense residential	Built Environment	Built Environment	Accurate
Chtaurama residential	Built Environment	Built Environment	Accurate
Kaya nursery	Built Environment	Built Environment	Accurate
Misc Residential quarters	Built Environment	Built Environment	Accurate
New construction	Built Environment	Built Environment	Accurate
Pain Royal	Built Environment	Built Environment	Accurate
mosque	Built Environment	Built Environment	Accurate
multiuse strip	Built Environment	Built Environment	Accurate
le pain magique	Built Environment	Built Environment	Accurate
fruit farm	Built Environment	Built Environment	Accurate
Marj monday market	Built Environment	Built Environment	Accurate
Infoset turned village	Built Environment	Built Environment	Accurate
Agri	Industrial	Built Environment	Inaccurate
Far7at new hospital	Construction	Built Environment	Inaccurate
Roadside fabric	Built Environment	Built Environment	Accurate
Old train station park campus	Natural Landscape	Built Environment	Inaccurate
Dense thick urban fabric Hayy el Ja'ir	Built Environment	Built Environment	Accurate
informal settlement	Built Environment	Built Environment	Accurate
Artificial pond / pool	Water	Built Environment	Inaccurate
Master Chips factory campus	Industrial	Built Environment	Inaccurate
Data point 80	Agriculture	Built Environment	Inaccurate

Data point 81	Industrial	Built Environment	Inaccurate
Data point 82	Industrial	Built Environment	Inaccurate
Data point 83	Industrial	Built Environment	Inaccurate
Data point 84	Industrial	Built Environment	Inaccurate
Data point 85	Industrial	Built Environment	Inaccurate
Al Mansoura	Built Environment	Built Environment	Accurate
Data 86	Built Environment	Built Environment	Accurate
Data 87	Built Environment	Built Environment	Accurate
Data 88	Built Environment	Built Environment	Accurate
Data 89	Natural Landscape	Built Environment	Inaccurate
Data 90	Built Environment	Built Environment	Accurate
Data 91	Industrial	Built Environment	Inaccurate
Data 92	Built Environment	Built Environment	Accurate
Sultan Yaakoub Tahta	Built Environment	Built Environment	Accurate
Ghazza	Built Environment	Built Environment	Accurate
Ghazza	Built Environment	Built Environment	Accurate
Ghazza	Built Environment	Built Environment	Accurate
Ghazza	Built Environment	Built Environment	Accurate
Ghazza	Built Environment	Built Environment	Accurate
data 100	Industrial	Built Environment	Inaccurate
Ghazza	Built Environment	Built Environment	Accurate
data 101	Built Environment	Built Environment	Accurate
data 102	Built Environment	Built Environment	Accurate
data 103	Built Environment	Built Environment	Accurate
Jeb Jannine	Built Environment	Built Environment	Accurate
Jeb Jannine	Built Environment	Built Environment	Accurate
mix fabric	Built Environment	Built Environment	Accurate
fabric data	Built Environment	Built Environment	Accurate
Tall el Za'aze'	Built Environment	Built Environment	Accurate
Khiara	Built Environment	Built Environment	Accurate
Khiara	Built Environment	Built Environment	Accurate
data 104	Built Environment	Built Environment	Accurate
data 105	Built Environment	Built Environment	Accurate
data 106	Built Environment	Built Environment	Accurate
data 107	Built Environment	Built Environment	Accurate
Zahle Maalaga	Built Environment	Built Environment	Accurate
Zahle Maalaga	Built Environment	Built Environment	Accurate
Zahle	Built Environment	Built Environment	Accurate
Caves de Ksara			
Campus	Built Environment	Built Environment	Accurate
Marj	Built Environment	Built Environment	Accurate
Marj	Built Environment	Built Environment	Accurate
Natural dp 02	Natural Landscape	Natural Landscape	Accurate
Natural dp 03	Natural Landscape	Natural Landscape	Accurate

Natural dp 04	Industrial	Natural Landscape	Inaccurate
Natural dp 05	Industrial	Natural Landscape	Inaccurate
Vacant land main road	Natural Landscape	Natural Landscape	Accurate
Riyyaq airport	Infrastructure	Infrastructure	Accurate
Bar Elias roundabout	Infrastructure	Infrastructure	Accurate
Gas station	Built Environment	Infrastructure	Inaccurate
Highway entry	Infrastructure	Infrastructure	Accurate
Chtaura dense centerline	Infrastructure	Infrastructure	Accurate
Service road	Infrastructure	Infrastructure	Accurate
Validation percentage			72.19%

## Appendix B: Validation Table for Article 03: Class 02

site_name	Class_Lev2	Class_name	Validation
Entrance from roundabout to bar elias	Functional Mix	Agriculture	Inaccurate
Bar Elias entrance from roundabout	Functional Mix	Agriculture	Inaccurate
Bar elias deir znoun corridor 1	Functional Mix	Agriculture	Inaccurate
Bar elias deir znoun corridor 2	Functional Mix	Agriculture	Inaccurate
Bar elias chafic jamil supermarket	Functional Mix	Agriculture	Inaccurate
Bar elias side rd	Land Cover Arid	Land Cover Arid	Accurate
PAC Taanayel corridor	Functional Mix	Agriculture	Inaccurate
Chtaura inner agri field	Agriculture	Agriculture	Accurate
Chtaura inner agri	Agriculture	Agriculture	Accurate
Anjar Main road	Land Cover Tree	Agriculture	Inaccurate
Water canal	Land Cover Arid	Agriculture	Inaccurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Mosque ozeir	Single Use / Development	Agriculture	Inaccurate
Agri infoset	Agriculture	Agriculture	Accurate
Camping ground	Land Cover Tree	Agriculture	Inaccurate
Public school	Facilities/Historic	Agriculture	Inaccurate
Residential neighborhood	Neighborhood	Agriculture	Inaccurate
Domaine de Chouchane	Land Cover Tree	Agriculture	Inaccurate
Vacant lot	Agriculture	Agriculture	Accurate
Recently shrubbed	Land Cover Tree	Agriculture	Inaccurate
Jeb Jannine waterway	Single Use / Development	Agriculture	Inaccurate
Jeb Jannine Node	Functional Mix	Agriculture	Inaccurate
Small Villas kamed	Functional Mix	Agriculture	Inaccurate
Agri wheat	Agriculture	Agriculture	Accurate
Pharmacy jhar commercial	Functional Mix	Agriculture	Inaccurate
Infoset established, also historic urban	Neighborhood	Agriculture	Inaccurate
Agri cabbage	Agriculture	Agriculture	Accurate
Pipe factory	Agriculture	Agriculture	Accurate
Cow hangar	Agriculture	Agriculture	Accurate
Villas on agri	Single Use / Development	Agriculture	Inaccurate
Nursery	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Ghazze park	Land Cover Arid	Agriculture	Inaccurate

معمل السكر	Industrial	Agriculture	Inaccurate
Agri natour house	Agriculture	Agriculture	Accurate
Public train park	Land Cover Tree	Agriculture	Inaccurate
Church on Agri field	Agriculture	Agriculture	Accurate
Water pump and collection lake	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Mashrou3 farz	Land Cover Arid	Agriculture	Inaccurate
Officer apt housing	Agriculture	Agriculture	Accurate
Amaleen	Water	Agriculture	Inaccurate
Mandara village	Land Cover Tree	Agriculture	Inaccurate
Farm	Agriculture	Agriculture	Accurate
Industrial	Industrial	Agriculture	Inaccurate
Agri land and construction	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri misc	Agriculture	Agriculture	Accurate
Ammiq Swamplands	Land Cover Tree	Agriculture	Inaccurate
Sett sha3wane mazar	Land Cover Arid	Agriculture	Inaccurate
Agri	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Agri terraces	Agriculture	Agriculture	Accurate
Sicomo	Land Cover Arid	Agriculture	Inaccurate
Agri potato	Agriculture	Agriculture	Accurate
Agri	Agriculture	Agriculture	Accurate
Serail jeb jannine neighborhood	Functional Mix	Agriculture	Inaccurate
Agri nursery	Agriculture	Agriculture	Accurate
Agri nursery	Land Cover Tree	Agriculture	Inaccurate
Qab Elias veggie market	Facilities/Historic	Agriculture	Inaccurate
Mekseh mix road	Functional Mix	Agriculture	Inaccurate
Public parklet	Agriculture	Agriculture	Accurate
Villa quarter	Land Cover Tree	Agriculture	Inaccurate
public petting zoo	Agriculture	Agriculture	Accurate
Horse barn	Agriculture	Agriculture	Accurate
Khiara entrance	Agriculture	Agriculture	Accurate
Agri land	Agriculture	Agriculture	Accurate
Agricultural terraces	Water	Agriculture	Inaccurate
Retention pond	Water	Agriculture	Inaccurate
Pond	Water	Agriculture	Inaccurate





Lebanese American University Campus	Facilities/Historic	Agriculture	Inaccurate
Ksara vinyard peripheries	Agriculture	Agriculture	Accurate
Ksara vinyard peripheries	Agriculture	Agriculture	Accurate
Marj	Neighborhood	Agriculture	Inaccurate
Haouch Harimeh	Neighborhood	Agriculture	Inaccurate
Haouch Harimeh	Neighborhood	Agriculture	Inaccurate
Multistory Kamed el Lawz	Functional Mix	Agriculture	Inaccurate
Cobra Tech	Functional Mix	Functional Mix	Accurate
PAC taanayel	Functional Mix	Functional Mix	Accurate
Chtaura villas	Single Use / Development	Single Use / Development	Accurate
Qab Elias Neighborhood	Functional Mix	Functional Mix	Accurate
Zahle Hw .1	Functional Mix	Functional Mix	Accurate
Zahle Hw .2	Land Cover Arid	Functional Mix	Inaccurate
Pop up coffee shop	Neighborhood	Functional Mix	Inaccurate
Residential neighborhood .2	Neighborhood	Functional Mix	Inaccurate
Residential neighborhood .1	Land Cover Tree	Functional Mix	Inaccurate
Residential neighborhood 2	Land Cover Tree	Functional Mix	Inaccurate
Recycling bin	Land Cover Tree	Functional Mix	Inaccurate
Gaidzag and Dzovig stadium	Facilities/Historic	Functional Mix	Inaccurate
Entrance commercial	Land Cover Arid	Functional Mix	Inaccurate
Gas station	Functional Mix	Functional Mix	Accurate
Commercial residential neighborhood	Functional Mix	Functional Mix	Accurate
Chtaura damas road neighborhood	Functional Mix	Functional Mix	Accurate
Al shams commercial mix	Functional Mix	Functional Mix	Accurate
Stargate	Functional Mix	Functional Mix	Accurate
Carré rouge mall	Functional Mix	Functional Mix	Accurate
Residential various	Functional Mix	Functional Mix	Accurate
Public park	Land Cover Tree	Functional Mix	Inaccurate
Commercial residential strip on frontage road	Functional Mix	Functional Mix	Accurate
Mosque	Neighborhood	Functional Mix	Inaccurate
Residential Jeb Jannine slope	Neighborhood	Functional Mix	Inaccurate
Old rail riyyak	Rail Dilapidated	Functional Mix	Inaccurate

Junkyard	Industrial	Functional Mix	Inaccurate
Soccer field	Facilities/Historic	Functional Mix	Inaccurate
Taalabaya main strip	Functional Mix	Functional Mix	Accurate
Taalabaya main commercial	Functional Mix	Functional Mix	Accurate
Commercial strip taalabaya	Functional Mix	Functional Mix	Accurate
Beauty women Hawana	Functional Mix	Functional Mix	Accurate
Vacant lot	Land Cover Arid	Functional Mix	Inaccurate
Ndj school	Facilities/Historic	Functional Mix	Inaccurate
Taalabaya school campus	Facilities/Historic	Functional Mix	Inaccurate
Church	Facilities/Historic	Functional Mix	Inaccurate
Taanayel commercial corridor	Functional Mix	Functional Mix	Accurate
Jalala main road neighnorhood	Functional Mix	Functional Mix	Accurate
Chtaura plaza	Functional Mix	Functional Mix	Accurate
Service corridor	Neighborhood	Functional Mix	Inaccurate
Taalabaya dense residential	Functional Mix	Functional Mix	Accurate
Chtaurama residential	Functional Mix	Functional Mix	Accurate
Roadside fabric	Functional Mix	Functional Mix	Accurate
Old train station park campus	Land Cover Tree	Functional Mix	Inaccurate
Al Mansoura	Neighborhood	Functional Mix	Inaccurate
	Neighborhood	Functional Mix	Inaccurate
	Neighborhood	Functional Mix	Inaccurate
	Neighborhood	Functional Mix	Inaccurate
Jeb Jannine	Neighborhood	Functional Mix	Inaccurate
	Single Use / Development	Functional Mix	Inaccurate
Caves de Ksara Campus	Facilities/Historic	Facilities/Historic	Accurate
PAC taanayel corridor waked electric	Single Use / Development	Neighborhood	Inaccurate
Pac taanayel corridor .1	Land Cover Arid	Land Cover Arid	Accurate
Pac taanayel corridor .2	Industrial	Neighborhood	Inaccurate
Bar elias inner neighborhood .1	Neighborhood	Neighborhood	Accurate
Bar elias inner neighborhood .2	Neighborhood	Neighborhood	Accurate
Bar elias inner neighborhood .3	Neighborhood	Neighborhood	Accurate
Bar elias plaza	Neighborhood	Neighborhood	Accurate
Refugee camp	Settlement Refugee	Neighborhood	Inaccurate
Mixed complex	Single Use / Development	Neighborhood	Inaccurate

Anjar Main road.2	Transportation	Neighborhood	Inaccurate
Mixed strip	Neighborhood	Neighborhood	Accurate
Ceramic store	Facilities/Historic	Neighborhood	Inaccurate
Mixed use Neighborhood			
WBQ	Neighborhood	Neighborhood	Accurate
Mosque	Functional Mix	Neighborhood	Inaccurate
Mix neighborhood	Functional Mix	Neighborhood	Inaccurate
Mix neighborhood	Functional Mix	Neighborhood	Inaccurate
Agri land infoset	Industrial	Neighborhood	Inaccurate
Residential	Neighborhood	Neighborhood	Accurate
Masnaa limit	Functional Mix	Neighborhood	Inaccurate
Commercial	Functional Mix	Neighborhood	Inaccurate
Heritage	Functional Mix	Neighborhood	Inaccurate
Anjar hwy commercial	Neighborhood	Neighborhood	Accurate
Highway	Land Cover Arid	Neighborhood	Inaccurate
Centre Khaled mix	Neighborhood	Neighborhood	Accurate
Parking lot	Neighborhood	Neighborhood	Accurate
Residential neighborhood	Neighborhood	Neighborhood	Accurate
Parking lot	Neighborhood	Neighborhood	Accurate
Doctor's offices	Functional Mix	Neighborhood	Inaccurate
Qab Elias Islamic school	Functional Mix	Neighborhood	Inaccurate
Popcorn factory	Neighborhood	Neighborhood	Accurate
Mix Neighborhood	Functional Mix	Neighborhood	Inaccurate
Mix neighborhood hwy	Neighborhood	Neighborhood	Accurate
Mix style residential neighborhood	Neighborhood	Neighborhood	Accurate
Notre Dame des Apotres	Facilities/Historic	Neighborhood	Inaccurate
Residential kamed villa neighborhood	Single Use / Development	Neighborhood	Inaccurate
Tile quarry sales	Industrial	Industrial	Accurate
Najah Steel	Industrial	Industrial	Accurate
Gas station	Functional Mix	Neighborhood	Inaccurate
Mill	Industrial	Industrial	Accurate
Granite reseller	Industrial	Industrial	Accurate
Ghazze inner road	Functional Mix	Neighborhood	Inaccurate
Public plaza	Functional Mix	Neighborhood	Inaccurate
Hopital riyyak	Facilities/Historic	Neighborhood	Inaccurate
Aryaf for food processing	Functional Mix	Neighborhood	Inaccurate
Infoset	Single Use / Development	Neighborhood	Inaccurate
Gececo	Industrial	Neighborhood	Inaccurate
مركز بر اليباس الصحي	Facilities/Historic	Neighborhood	Inaccurate
Bar elias hospital	Facilities/Historic	Neighborhood	Inaccurate

Agri wheat	Agriculture Crop	Neighborhood	Inaccurate
Kaya nursery	Functional Mix	Neighborhood	Inaccurate
Misc Residential quarters	Functional Mix	Neighborhood	Inaccurate
New construction	Functional Mix	Neighborhood	Inaccurate
Pain Royal	Functional Mix	Neighborhood	Inaccurate
mosque	Facilities/Historic	Neighborhood	Inaccurate
le pain magique	Functional Mix	Neighborhood	Inaccurate
fruit farm	Functional Mix	Neighborhood	Inaccurate
Marj monday market	Facilities/Historic	Neighborhood	Inaccurate
Far7at new hospital	Under Construction	Neighborhood	Inaccurate
Dense thick urban fabric			
Hayy el Ja'ir	Functional Mix	Neighborhood	Inaccurate
informal settlement	Single Use / Development	Neighborhood	Inaccurate
Master Chips factory			
campus	Industrial	Neighborhood	Inaccurate
	Single Use / Development	Neighborhood	Inaccurate
	Single Use / Development	Neighborhood	Inaccurate
	Single Use / Development	Neighborhood	Inaccurate
	Land Cover Tree	Neighborhood	Inaccurate
	Settlement Refugee	Neighborhood	Inaccurate
Sultan Yaakoub Tahta	Single Use / Development	Neighborhood	Inaccurate
Ghazza	Neighborhood	Neighborhood	Accurate
Ghazza	Functional Mix	Neighborhood	Inaccurate
Ghazza	Neighborhood	Neighborhood	Accurate
Jeb Jannine	Neighborhood	Neighborhood	Accurate
	Single Use / Development	Neighborhood	Inaccurate
Tall el Za'aze'	Functional Mix	Neighborhood	Inaccurate
Khiara	Neighborhood	Neighborhood	Accurate
	Single Use / Development	Neighborhood	Inaccurate
	Single Use / Development	Neighborhood	Inaccurate
	Single Use / Development	Neighborhood	Inaccurate
Zahle Maalaqa	Functional Mix	Neighborhood	Inaccurate
Zahle Maalaqa	Functional Mix	Neighborhood	Inaccurate
Zahle	Neighborhood	Neighborhood	Accurate
Marj	Neighborhood	Neighborhood	Accurate
Marj	Neighborhood	Neighborhood	Accurate
Pac taanayel	Industrial	Industrial	Accurate
Neighborhood	Neighborhood	Industrial	Inaccurate
Residential under construction	Land Cover Arid	Industrial	Inaccurate
Sayed farm	Industrial	Industrial	Accurate
Az manufacturing	Industrial	Industrial	Accurate
Najjar and kassatly	Industrial	Industrial	Accurate

Agri	Industrial	Industrial	Accurate
Artificial pond / pool	Water	Water	Accurate
	Industrial	Industrial	Accurate
	Industrial	Industrial	Accurate
	Industrial	Industrial	Accurate
	Industrial	Industrial	Accurate
	Industrial	Industrial	Accurate
Ghazza	Functional Mix	Industrial	Inaccurate
Ghazza	Neighborhood	Industrial	Inaccurate
	Industrial	Industrial	Accurate
	Single Use / Development	Single Use / Development	Accurate
Residential neighborhood	Neighborhood	Single Use / Development	Inaccurate
Mix neighborhood	Functional Mix	Single Use / Development	Inaccurate
Commercial neighborhood	Functional Mix	Single Use / Development	Inaccurate
Mix commercial mn rd	Functional Mix	Single Use / Development	Inaccurate
Arcada neighborhood	Functional Mix	Single Use / Development	Inaccurate
Construction commercial strip	Functional Mix	Single Use / Development	Inaccurate
Agri wheat	Single Use / Development	Single Use / Development	Accurate
multiuse strip	Functional Mix	Single Use / Development	Inaccurate
Infoset turned village	Neighborhood	Neighborhood	Accurate
	Single Use / Development	Single Use / Development	Accurate
Khiara	Neighborhood	Neighborhood	Accurate
Fancy Church	Facilities/Historic	Facilities/Historic	Accurate
	Land Cover Arid	Land Cover Arid	Accurate
	Land Cover Arid	Land Cover Arid	Accurate
	Industrial	Land Cover Rock	Inaccurate
	Industrial	Land Cover Rock	Inaccurate
Vacant land main road	Land Cover Tree	Land Cover Tree	Accurate
Riyyaq airport	Transportation	Transportation	Accurate
Bar Elias roundabout	Transportation	Transportation	Accurate
Gas station	Functional Mix	Transportation	Inaccurate
Highway entry	Transportation	Transportation	Accurate
Chtaura dense centerline	Transportation	Transportation	Accurate

Service road	Transportation	Transportation	Accurate
Accuracy %			57.69%