**International Journal of Applied Geospatial Research**
Volume 14 • Issue 1

# Estimating the Population of a Middle Eastern City Based on a Normalized Difference Built-Up Index and Urban Morphology

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## ABSTRACT

The aim of this study is to introduce a method for estimating the population of a Middle Eastern city, the city of Hillah, in the absence of a census which was last conducted in 1997. The method incorporates the normalized difference built-up index and land use-land cover information to identify residential areas for four years 1987, 1997 (the last census), 2008, and 2018 using Landsat imagery. Dasymetric mapping is employed to rezone residential pixels to the city's administrative districts or mahallahs. Mahallah populations for each year are estimated using local and historical urban morphology characteristics combined with standardized housing and household sizes. The result of this study is a range of estimates for mahallah populations, but a reasonable estimate of the city of Hillah's population is developed. The use of historical information, urban design, and environmental data with remote sensing methods in a Middle Eastern context provides an added tool in the arsenal of population estimation techniques.

## KEYWORDS

Dasymetric Maps, GIS, Mahallah, Normalized Difference Built-Up Index, Remote Sensing, Urban Morphology

## INTRODUCTION AND BACKGROUND

### Introduction

Human populations and settlements are dynamic processes that yield heterogenous spatial patterns and geographies (Azar et al., 2013). Detailed population data are essential for evidence-based decision-making and for public and private organizations concerned with risk management, vulnerability assessment, health care provisioning, and development goals (Grippa et al., 2019; Wardrup, 2018). Knowledge of a population's spatial distribution is also important for planning

DOI: 10.4018/IJAGR.313942 *Corresponding Author

infrastructure and service needs as well as assessing taxes. The mapping of a community's population distribution and its associated social, economic, and demographic characteristics is an essential first step in any urban management and planning process (UNSD—Demographic and Social Statistics, n.d.; Berke et al., 2006).

Many developing and low-income countries lack accurate population data due to high costs of conducting and maintaining censuses. Political issues and the nature of governmental regimes can also affect census reliability and validity (Azar et al., 2013). From census to census, enumeration area boundaries may shift reflecting changes in population densities resulting from differences in settlement histories, regime changes, and the redesign of administration boundaries. For these reasons, the lack of reliable population data across small areas necessitates the use of relatively low-cost estimation techniques which are used to assist in development programs. The United Nations is one organization that relies on population estimates for many countries and cities such as Mexico City and Riyadh in Saudi Arabia for such purposes (Sutton et al., 2001).

In Iraq, the Ministry of Planning and Public Works and the Ministry of Transportation and Roads were historically responsible for conducting the national census every 10 years. However, recent political events and changing government regimes have brought the census to a halt, leading to a lack of accurate population data. The last official census for the City of Hillah was in in 1997 (UNSD—Demographic and Social Statistics, n.d.). Since that time, population has been estimated by the Ministry of Planning each year by extrapolating from census data collected in 1997 using assumed annual growth rates for each administrative area.

Estimates based on annual population growth are limited and do not account for evolving policies, planning decisions, and socio-economic factors that can affect growth. Urban populations will vary over small areas because of differences in natural increases or decreases and migration resulting in variegated spatial and temporal density patterns. Simple extrapolation without considering socio-economic and political factors can result in an accumulation of estimation errors. Using administrative units or population counts assigned to pixels to create weighted populations is another means that can provide coarse estimates of population densities. However, the results from this method can be plagued by changes in administration boundaries, pixel misclassification, or incorrect weighting of population per geographical unit (Cockx & Canters, 2015; Mennis, 2003; Wu and Murray, 2007).

Another approach in population estimation entails differentiating and accumulating populations based on their associations with Land Use (LU) and Land Cover (LC). LU represents the activities that humans perform in locations categorized as residential and industrial areas, commercial, education, healthcare facilities, and public land uses. LU categorization can provide valuable complementary information for modeling populations using Remote Sensing (RS) techniques. LC is related to the physical characteristics of earth surface features such as vegetation, water, soil, and built-up areas. RS is used to collect information on both human activity and the physical environment through reflected energy signatures measured at a distance for analyzing the distribution of the spectral, radiometric, temporal change characteristics and properties of the urban spatial structure (Azar et al. 2013; Deng et al., 2010; Li et al., 2005; Lu, 2006; Myint et al., 2011; Wardrop et al., 2018; Wu and Murray, 2007; Yang, 2011; Zandbergen et al, 2010).

In the absence of low-cost and rapid localized micro-surveys, spatial information such as urban morphology (UM) can also be used for estimating population. The sizes and shapes of domiciles can be associated with average numbers of people living in households and then aggregated to approximate the number of residents. Additionally, urban morphological forms can be categorized as either unplanned or planned and further associated with historical periods of urban development. For Middle Eastern cities, several urban forms are found. In the case of the City of Hillah, unplanned shapes of urban design are characterized by narrow road geometries and small, high density housing units. For example, unplanned shapes are characteristic of the first Urban Morphology (UM) period in the City of Hillah and found within the historical core of the city. Planned shapes of urban design, typically larger and more regular, appear in following UM periods until later when, due to political